Materials & Methods

Selection & use of

metals, nonmetallics, parts, finishes

in product design & manufacture

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November 1955

Corrosion: How It Affects Materials Selection and Design—M & M Manual No. 121

Fluorocarbon Dispersion Coatings

Fiber Metals—A New Metal Form

Roll Formed Sheet Metal Parts

Flame Hardened Ductile Irons

New Fiber-Reinforced Fluorocarbon

Nickel-Plated Steel Sheet and Plate

Standards for Metal Powders and Metal Powder Products

Complete Contents—page 1

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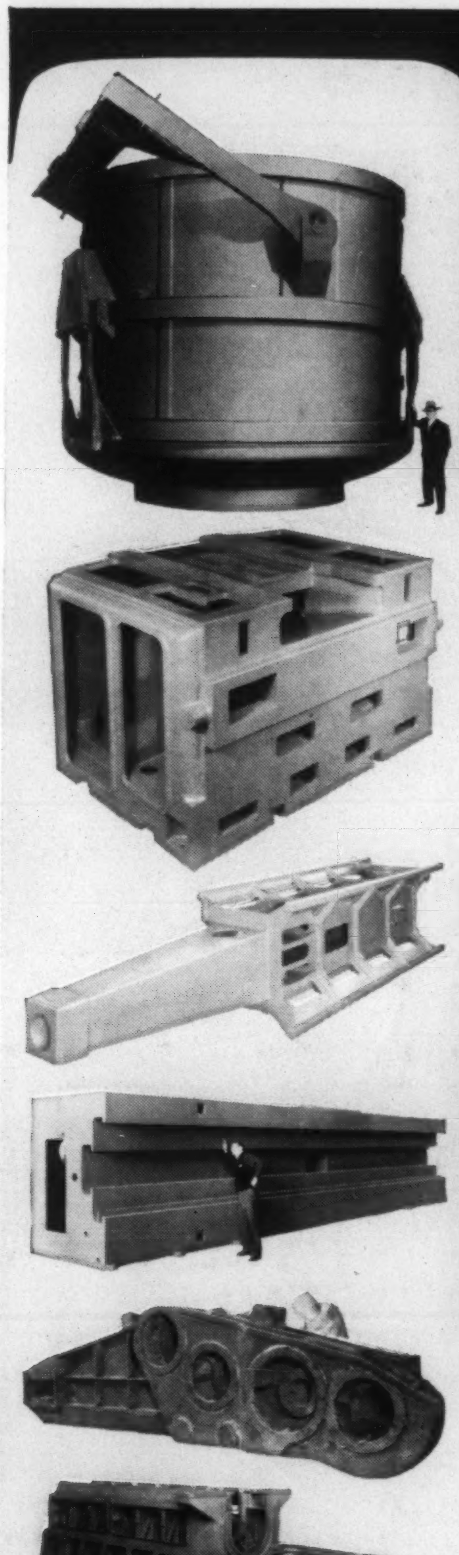

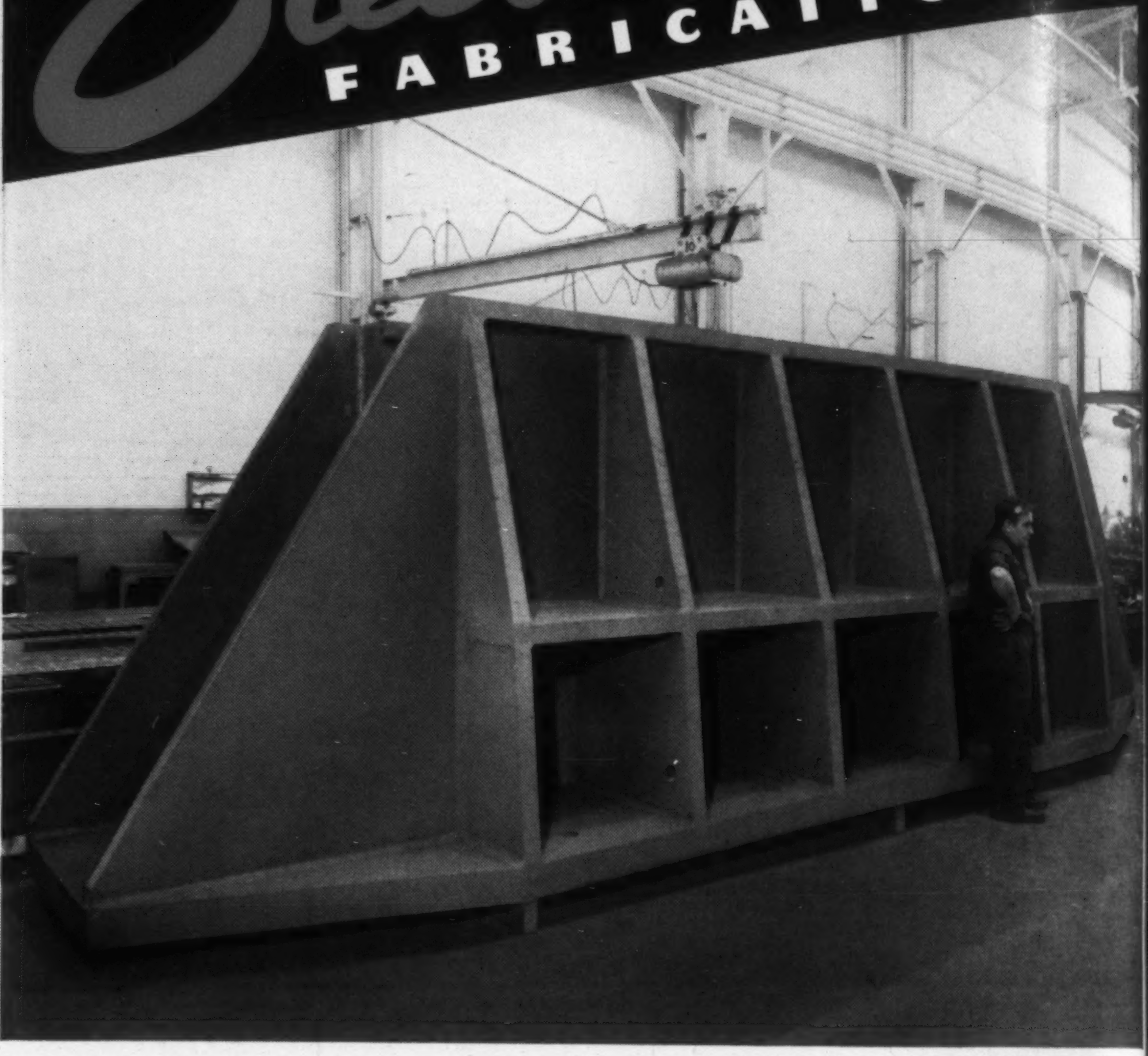

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NOVEMBER 1955 **VOL. 42, NO. 5**

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Materials & Methods is indexed regularly in the Engineering Index and the Industrial Arts Index

FEATURE ARTICLES

Fluorocarbon Dispersion Coatings .... *Gene Bartczak* **90**
What they are, what they can do, and where to use them

Fiber Metals—A New Metal Form .... *A. G. Metcalfe, C. H. Sump* **96**
Metal sheet made by paper making techniques shows promise for porous parts

Roll Formed Sheet Metal Parts .... *E. J. Vanderploeg* **100**
Many metals can be roll formed to close tolerances at high production rates

Plastics Extrusions Make Good Handles .... *Robert Marx* **104**
Case histories demonstrate the low cost, attractive shapes that are possible

Flame Hardened Ductile Irons .... *C. E. Ernst, R. V. Adair, G. L. Cox* **106**
Wear resistance significantly increased when proper procedures are used

New Fiber-Reinforced Fluorocarbon .... *Norman L. Greenman* **110**
Excellent resistance to distortion and cold flow now added to other desirable qualities of fluorocarbons

Nickel-Plated Steel Sheet and Plate .... *L. L. Williams* **112**
A new corrosion-resistant workable material for process and chemical equipment

How to Avoid Brittle Failures in Steel .... *G. H. Enzian* **116**
A practical explanation of notch brittleness and ways to avoid it

Plastics-Rubber Pressure Seals .... *E. N. Gomberg* **142**
By replacing an aluminum receptacle, this nonmetallic cuts weight, reduces costs

Materials at Work **99, 103, 115**
Glass Insulates Ground. Aluminum Tire Mold. Low Cost Die Casting

MATERIALS & METHODS MANUAL NO. 121

Corrosion: How It Affects Materials Selection and Design .... *R. W. Henke* **119**

ENGINEERING FILE FACTS

Standards, Specifications and References for Metal Powders and Metal Powder Products **137**

DEPARTMENTS

Materials Outlook **3**
Materials Briefs **7**
Men of Materials **9**
Materials Engineering News **11**
Reader Service **67**
Manufacturers' Literature **68**
One Point of View **89**
New Materials, Parts, Finishes **149**
Contents Noted **189**
News of Engineers, Companies, Societies **222**
Meetings & Expositions **236**
Advertisers and Their Agencies **296**
Last Word **298**

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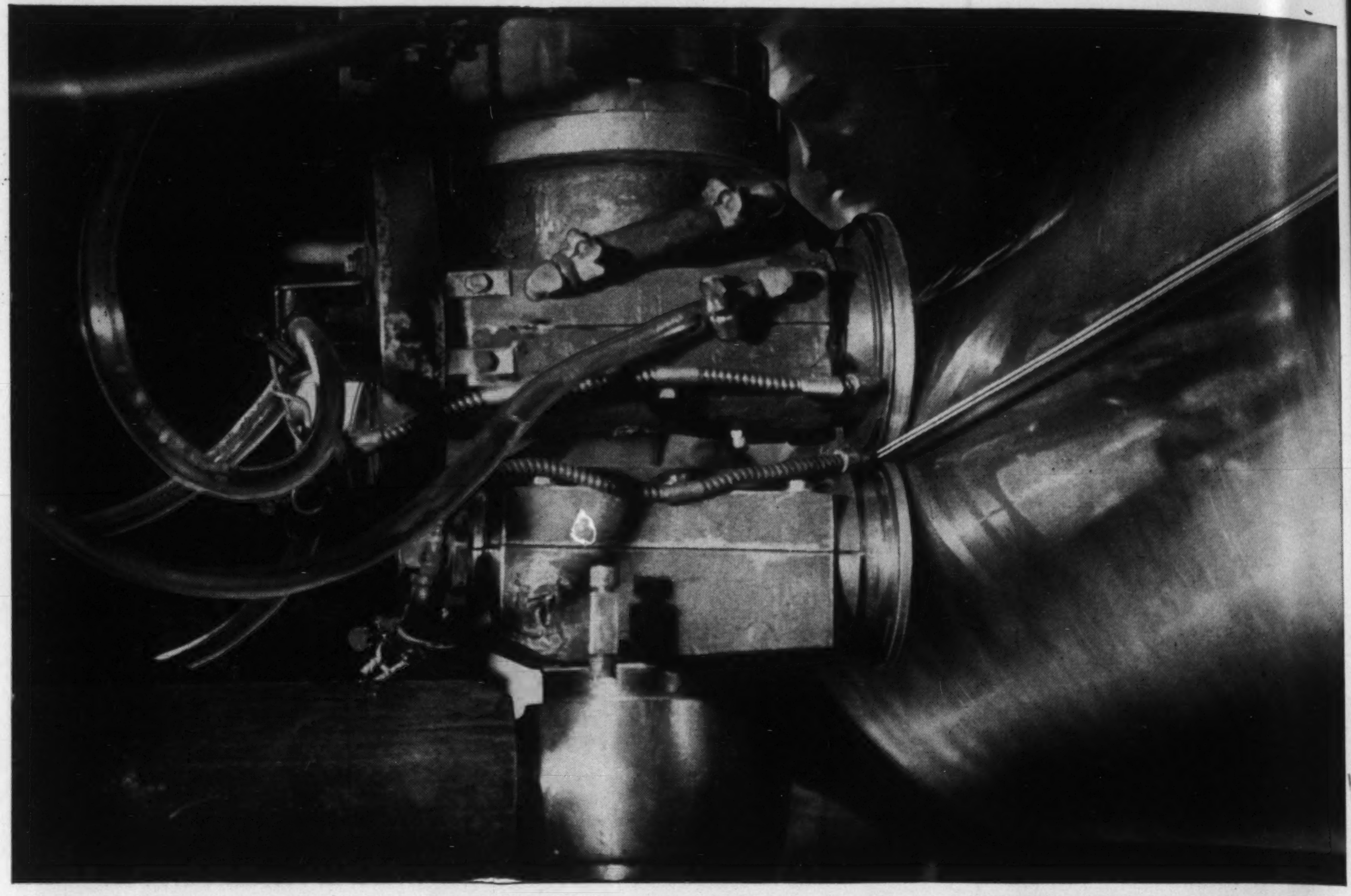

Skyline's Production Line methods such as this seam welding operation have reduced prices of Monel nickel-copper alloy tanks to a point within reach of most boat owners. This and other Inco Nickel alloys provide superior fabrication and mechanical properties. That's why Inco alloys are widely used in Skyline products.

Bill Jung doubles company's size and business…

MONEL helps young engineer break cost barrier

A year ago, BILL JUNG, a successful engineer, headed a small company that fabricated air-borne equipment exclusively.

Today, his company . . . SKYLINE PRODUCTS, INC., Deer Park, Long Island, New York . . . is twice as big. All because Bill Jung had a bright design idea that was made practical by Monel* nickel-copper alloy.

Watching his Sciaki spot and seam welders speed the output of aircraft weldments, Bill reasoned: why not use this method to weld fuel and water tanks for boats . . . resistance welding would cut the cost.

He checked with boat builders. He found not only definite interest, but also universal preference for Monel alloy because of its strength and corrosion resistance.

$40 cut from cost

However, not everybody could afford this alloy. Bill learned that hundreds of tanks were made of materials like steel or copper, coated with zinc, tin or lead to cut costs. But unlike Monel nickel-copper alloy, these materials do not respond to resistance welding.

Bill set up to make tanks by resistance welding. And typical of the result, Skyline now sells a welded Monel fuel tank for $85. The same size tank used to cost $125.

Along with fuel and water tanks, Skyline now produces hardware for boats, and other equipment made of Monel alloy. Because this alloy is tough, long-lasting, and corrosion-resisting all the way through, it withstands heat and cold as well as many acids, alkalies and salts. It's a material for use where you want strength and corrosion resistance . . . as well as low-cost production.

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Materials Outlook

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LATEX PAINTS FOR METAL PRODUCTS may come into their own before too long. Heavy competition among acrylic, polyvinyl acetate and styrene-butadiene emulsion paints in the "trade" field has tended to slow up the development of satisfactory industrial product coatings, but several companies hope to dent the industrial market in the near future.

OXIDATION-RESISTANT BORON NITRIDE, currently available from Carborundum in limited quantities as dense, hot pressed cylinders, has relatively low density, high electrical insulating ability, excellent thermal shock resistance, high thermal conductivity at high temperatures, good lubricating qualities and many other useful properties. Combinations of boron nitride with various ceramics and metals also show promise . . . . . . IMPERMEABLE SILICON CARBIDE, suitable for containing fluids, is also available. A new process fills up the usual pores with additional silicon carbide, providing greater resistance to erosion and abrasion, as well as virtual lack of permeability.

WAREHOUSE STOCKS OF STEEL HAVE BEEN GREATLY DEPLETED by current high demand. Rebuilding inventories to previous levels will probably require several months to a year, depending on demand in the next few months.

A STRONG, RIGID SANDWICH MATERIAL with infinite decorative possibilities, developed by Englander, consists of metal, cloth or paper honeycomb core bonded to clear or translucent polyester-glass cloth skins that allow the hexagonal honeycomb pattern to show through. Many different effects can be achieved by varying sandwich thickness, skin colors, honeycomb weight and honeycomb color. With aluminum honeycomb, a highly efficient light transmission panel can also be produced.

CENTRIFUGAL CASTINGS aren't as popular as they used to be, according to an important foundry which has now decided to get out of this field. Many parts formerly made in one piece by centrifugal casting are now being made by welding together several forgings.

A ONE-COMPONENT EPOXY RESIN ADHESIVE has been developed. By eliminating the necessity for weighing and mixing-in a separate hardener, it makes adhesive bonding of metal or rigid plastic parts much more practical for mass production applications. The new adhesive is also thixotropic, enabling the user to maintain a vertical glue line during curing.

NATURE OF THE 'FLAME-PLATING' PROCESS for applying thin tungsten carbide coatings to metal surfaces at temperatures of 400 F or less has finally been revealed by Linde after three years. Method

Materials Outlook

uses a gun which is loaded with measured quantities of tungsten carbide powder, oxygen and acetylene. When the mixture is ignited by a spark, the gases explode from the barrel, carrying the partially molten carbide onto the metal surface in a series of loud blasts.

MICROSCOPIC EXAMINATION OF GLASS-REINFORCED PLASTICS shows up nonuniform distribution of resin and fiber, as well as internal cracks incurred in service at stress levels below the ultimate strength of the material. Techniques for polishing and proper field lighting have been developed; neither staining nor etching seem to be necessary.

ADVANTAGES OFFERED BY METAL-METALLIC OXIDE SINTERED CONTACT materials are becoming more obvious as appliance designers strive to increase current-carrying capacity or reduce size without running up costs. Silver-cadmium oxide and similar contacts have much greater load-carrying capacity than silver and are less expensive and more oxidation-resistant than the refractory metal types used in heavy equipment.

ELECTROLYTIC HEATING, a Russian-developed process, shows some promise for heat treatment and joining of nonferrous metals. The metal or metals to be heated are made the cathode in an electrolytic cell, and voltage is increased to the point where the cathode is blanketed by hydrogen and no longer cooled by the electrolyte. Thermocouple wires have been welded together with about 1% of the current required by resistance welding.

MORE ALUMINUM FORGINGS is current aim of Harvey Aluminum which has launched an extensive development program intended to acquaint designers and engineers with possibilities offered by new heavy presses now in operation. Orthopedic appliances, portable tool handles, textile machinery components, Diesel engine pistons, and hardware for luggage and transportation equipment are some of the applications being studied.

DYED MYLAR FILM is available in pilot plant quantities. In addition to having more lightfast colors, better abrasion resistance and better heat resistance than coated film, dyed film can be given a matte finish, thereby opening up a range of softer metallic colors for metallized film applications.

A NEW TEST FOR ABRASION RESISTANCE OF ORGANIC COATINGS involves directing a jet of fine abrasive particles against the surface under carefully controlled conditions of pressure, distance, angle and flow. Abrasion resistance is measured by the time required to abrade through a unit thickness of coating. The method, developed at NBS for the Navy, appears to be rapid, simple, and one of the most reproducible tests available.

Materials BRIEFS

Molding With Holes
Latest plastics foam development eliminates foaming agents by starting with hollow spheres or "microballoons" instead of liquid. Spheres are bonded together by a liquid agent added at time of application.

20,000 for a Penny
Least expensive dosimeter for radiation is a small piece of cellophane. Blue cellophane fades out on exposure to gamma rays, is used to indicate heavy dosage needed for sterilization.

No Material
A radio loudspeaker without a vibrating membrane has been developed by a German concern. Device uses a vibrating pocket of ionized air instead of speaker cone, claims higher fidelity results.

Indium Cell
An expendable battery the size of a penny can deliver a constant voltage continuously for two years. Indium anode eliminates gassing.

Long Shot In
Total U.S. research expenditures over the last 25 years total $30 billion, but have given a 13-1 return on investment according to studies conducted by a leading electronics firm.

Exhaust Shield
Underwing corrosion from exhaust gases from aircraft engines can be eliminated by a thin shield of Mylar. Kit is available for application.

Protector
A percent or two of tin added to high purity reactor quality zirconium increases the metals corrosion resistance significantly, without increasing neutron absorption.

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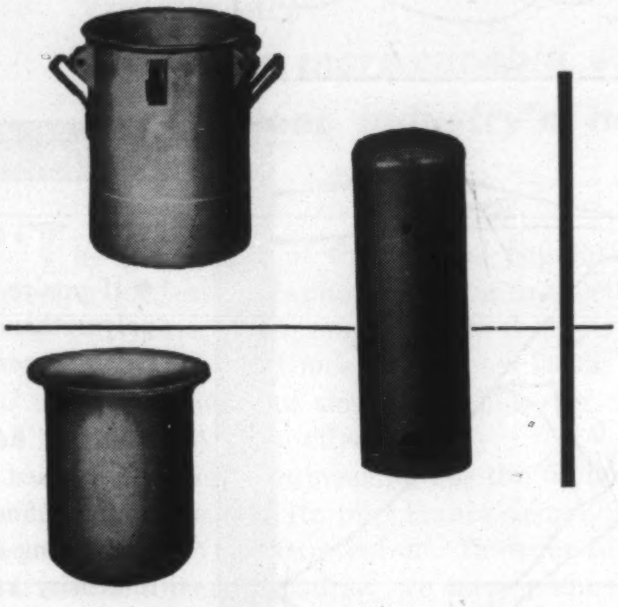

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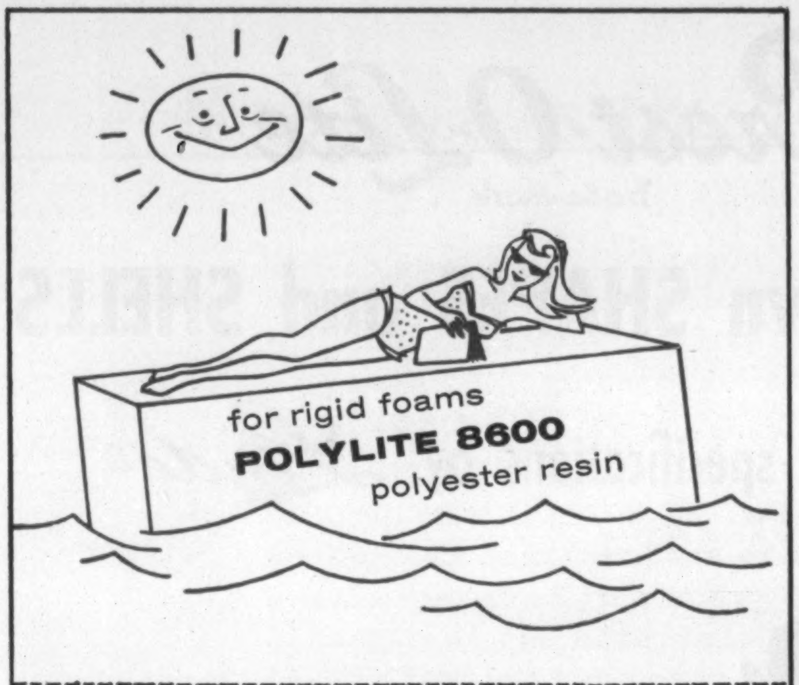

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POLYLITE 8650
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Men of Materials...

Dr. John P. Nielsen, chairman of New York University's Dept. of Metallurgy, is a strong proponent of materials engineering education for both students and practicing engineers. Dr. Nielsen's career includes, besides academic work, professional association with Chase Brass & Copper, McGean Chemical Co., International Nickel, and North American Phillips Laboratories. He was graduated from Michigan College of Mining and Technology, and received his doctorate from Yale, where he was a National Research Council Fellow. He is President of the New York Chapter of ASM, and can be credited with initiating many of the Society's successful educational programs. Dr. Nielsen's background of academic and industrial experience makes him a valued consultant to both industry and his students.

Nielsen says:

"Fewer, more capable, engineers will meet industry's needs . . .

"The percentage of the general population entering the engineering profession cannot continue to accellerate as it has in the past 100 years, since engineers in that period have increased in number at a rate 25 times that of population growth. The demands of technology will not slow down, however, so that every engineer will have to be more effective.

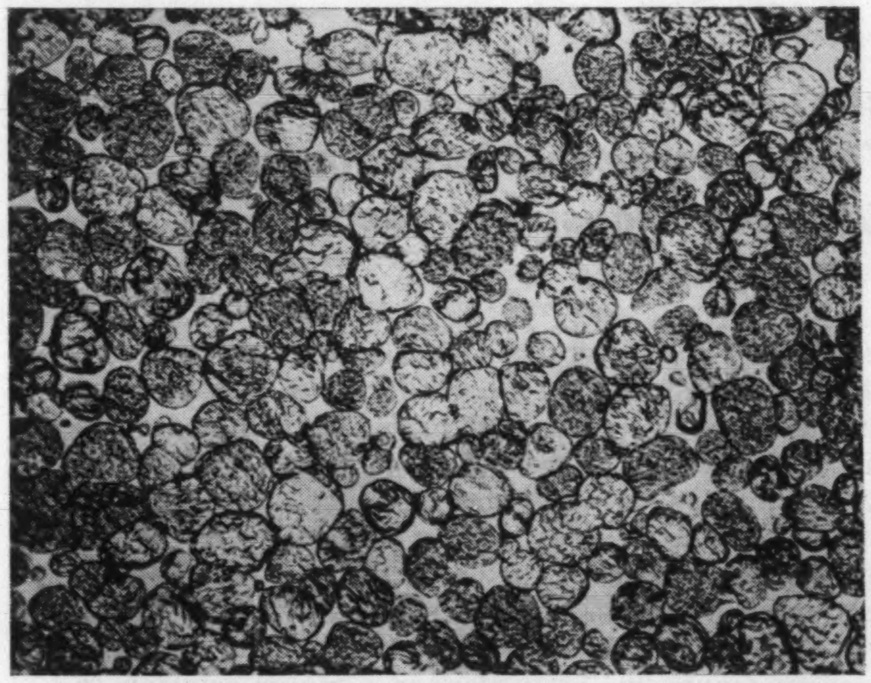
"Materials engineering for the undergraduate may be only a single course, but its importance demands that it be one of the best courses in the curriculum. In order to improve our own materials engineering course, we have planned a major revision in focus, concentrating on the mechanisms for solving materials engineering problems. Our primary objective will be to place the student in the position of engineering designer. He will itemize, from an active point of view, the conditions to which materials are subject in given applications. For example, in addition to determining the static load on a structural member, he will try to anticipate such conditions as vibrational stress, fatigue, impact, corrosion, wear, friction, temperature, pressure, lifetime and aging factors, fabrication demands, electrical and mechanical conditions, optical or radiant energy features, and finally, the important concept of 'cost per unit of service'. Briefly stated, students must learn to make a sufficiently exhaustive analysis to guarantee that no ordinary conditions have been overlooked that materials might encounter in the lifetime of a producible product.

"Following the study of service factors, the student will proceed with a survey of specific materials in terms of their ability to meet specific requirements. In this phase, he will learn properties of materials from the standpoint of the designer's frame of reference. Such a course lends itself naturally to the case method of study. Beginning with simple problems, such as ship ballast or tableware materials, we will proceed through more complex case histories to a final study of an unsolved problem involving extreme conditions, e.g. the heat in an atomic explosion, to challenge the more imaginative students.

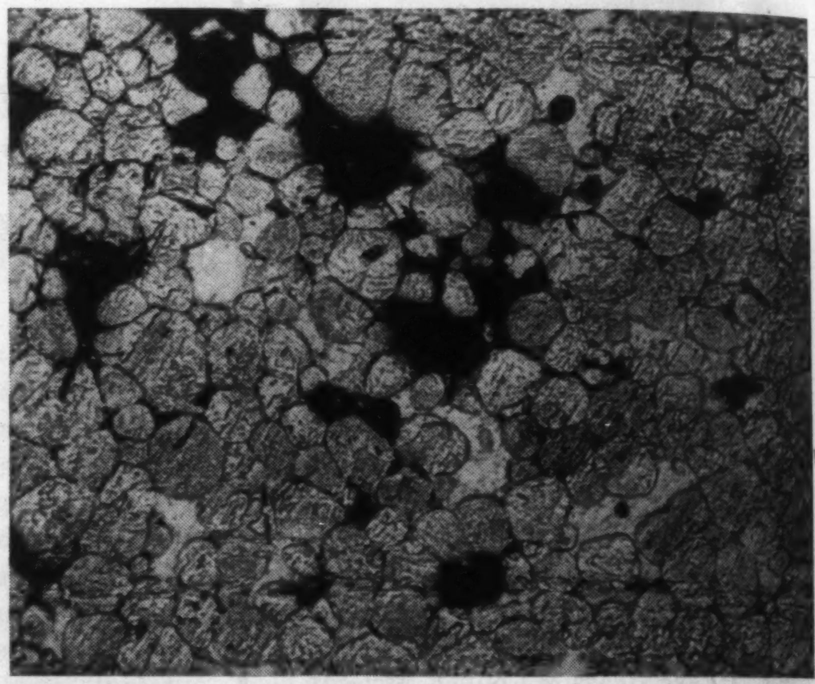
"On completion of such a materials engineering course, we hope our students will have a clear idea of how materials problems are solved. Furthermore, by experiencing the challenge to the designer and learning to use the tools of materials engineering, the student should be more capable of meeting the challenge of the increasing complexity of modern technology."

Uniform Structure

of Mallory 1000 Metal assures effective radiation shielding



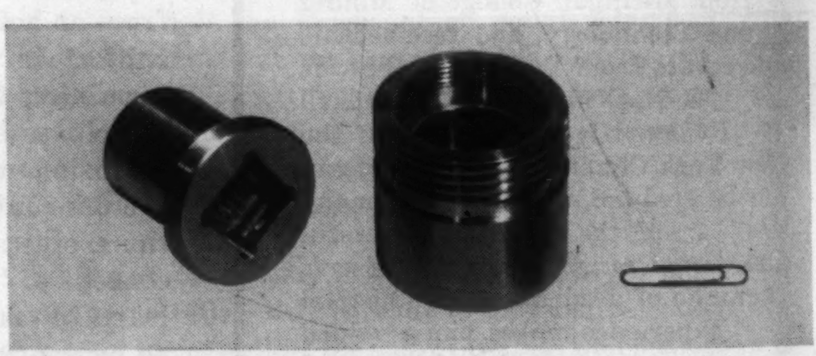
Mallory 1000 Metal, under high magnification, shows completely uniform grain structure. Its high density extends through every part of the piece . . . free from voids and weak spots.



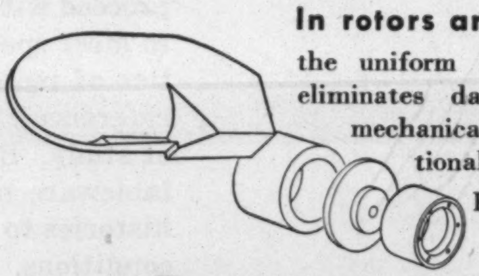
Voids in less uniform metals look like this under the microscope. They seriously impair shielding effectiveness and tend to make performance unpredictable.

When you design radiation shields with Mallory 1000 Metal, you can figure on the basis of *accurate* characteristics . . . instead of having to estimate on "typical" values. You can predict performance of your design precisely, because every piece of Mallory 1000 is produced to the same, precisely controlled qualities . . . and, most important, these qualities are completely uniform *throughout each piece* of the metal.

Up to 40% more effective than lead, Mallory 1000 is being used for shielding at energy levels up to 100 MEV. It has excellent weathering qualities, and machines to a high surface finish. Intricate shapes are produced economically to accurate tolerances by exclusive Mallory contour pressing methods. For complete data, write to Mallory for Technical Bulletin 6-7.



Typical source capsules made of Mallory 1000 provide "leakproof" shielding.



In rotors and counterweights, the uniform structure of Mallory 1000 eliminates danger of unbalance. High mechanical strength, density and rotational inertia make possible smaller parts, faster rotational speeds.

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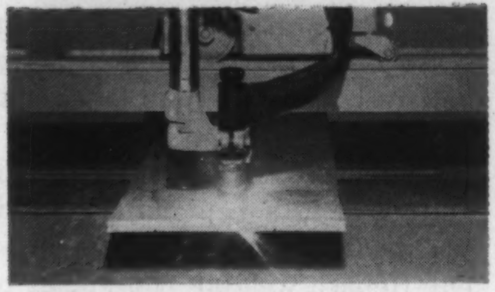
MATERIALS ENGINEERING NEWS

NOVEMBER 1955

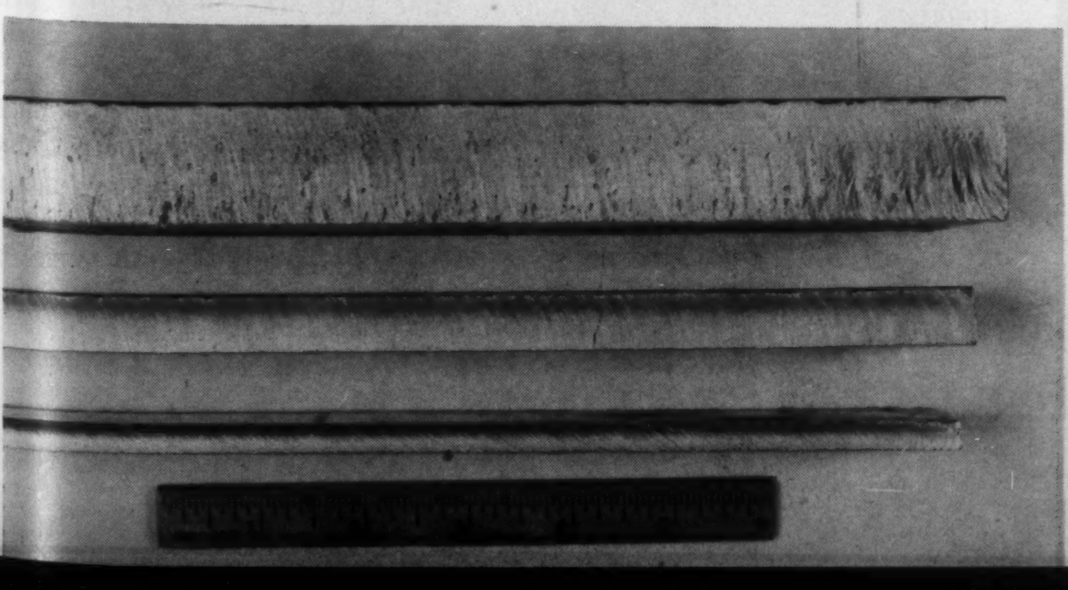


Arc Cutting Aluminum ▸ More Synthetic Mica ▸ Ceramic Tooling ▸ Titanium Status ▸ Zirconium Supply ▸ Copper Price Battles ▸ Nuclear Congress ▸ Low-Nickel Stainless

Constricted Arc Slices Aluminum

New cutting method speeds aluminum fabrication

Saw-like cuts *in aluminum were made at high speed with machine feed.*



■ A new process for shaping nonferrous metals that promises to have great significance was unveiled at the Metal Show in mid-October. The process, called Heliarc cutting, rivals in cutting rate and performance oxygen cutting techniques used for iron and steel. Instead of a jet of oxygen, a directional, gas-shielded electric arc slices through aluminum at high cutting speed, leaving a thin kerf with saw-cut quality edges.

Increase in cutting speed and reduction of edge preparation after cutting almost ensure that the new process will be adopted by many aluminum sheet fabricators. Take a typical example of current practice in shaping ⅝-in. aluminum sheet for welded tanks: the stock is cut at the rate of 1 in. per min using a combination of drilling and chipping or burning and chipping, then the edges must be further prepared by planing, which averages about 10 in. per min including set up time and handling operations. The new shielded arc cutting torch, manually operated, will average about 60 in. per min, leaving edges with square corners and no attached dross. Mechanized, the Heliarc cutting process is even faster, cutting aluminum at the following rates with different thicknesses of stock:

Thickness (in.)	at	Speed (ipm)
¼	—	300
½	—	125
¾	—	75
1	—	50

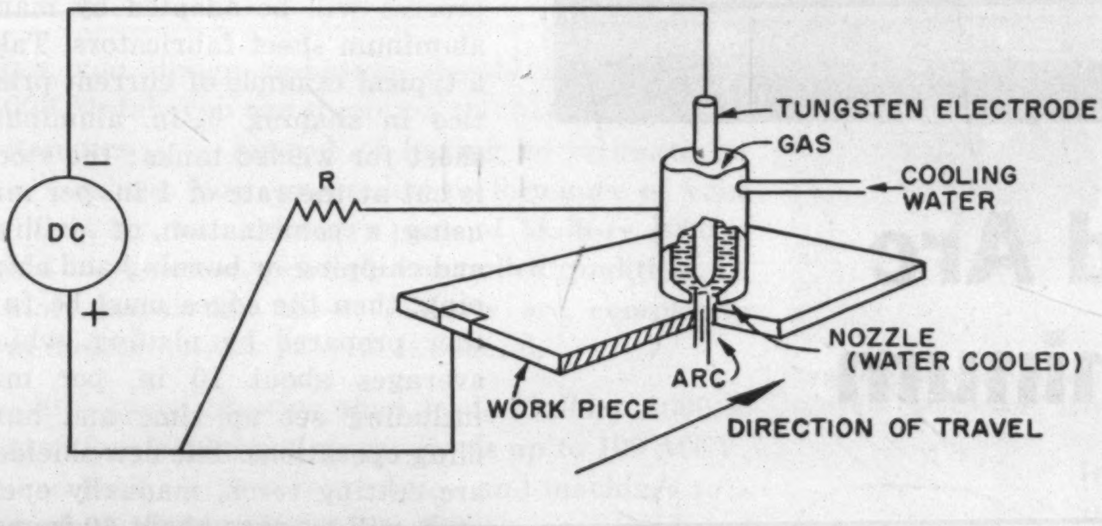
Bevelled and angular cuts present no problems with the process, and cuts can be straight or curved. Lower cutting speeds than those in the table are achieved by relatively simple control adjustments.

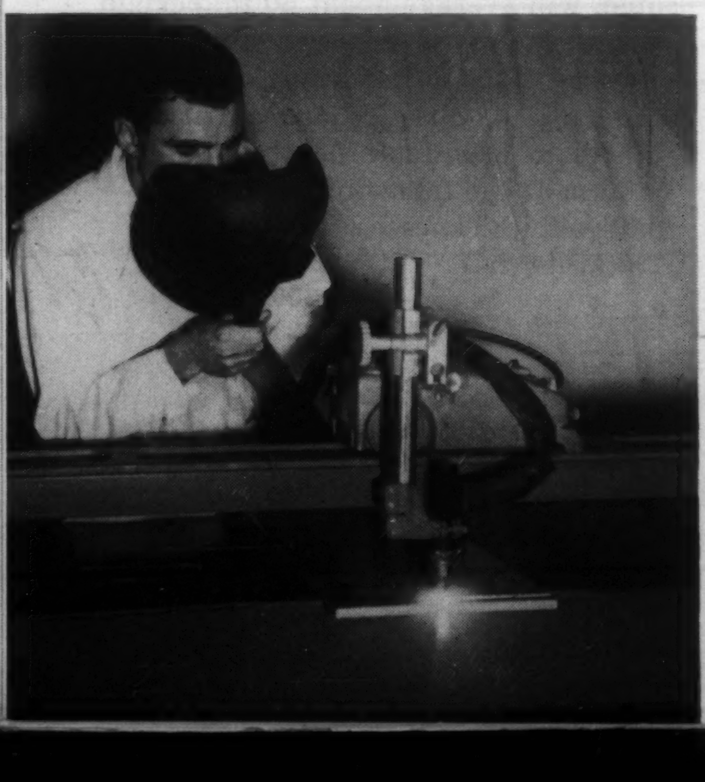
The heart of the arc cutting system is in a new cutting head, which allows conversion of present Heliarc welding equipment to arc cutting with a minimum of changes. The process employs a high-temperature, high-velocity "constricted" arc between a tungsten electrode and the work piece. The concentrated, columnated energy of the arc stream melts and ejects a thin section of metal to form a kerf, while the gas atmosphere (65% argon, 35% hydrogen for machine cutting) prevents oxidation of the cut faces. The nature of the directional arc permits piercing operations to form holes in stock up to maximum cutting width. The straight sided holes so produced must have a minimum diameter equivalent to the cutting kerf, which is approximately 3/16 in. ± 1/32 in.

To convert existing Heliarc welding equipment for cutting, the only change required in addition to the nozzle change is the addition of an electrical circuit for the pilot arc used to initiate the cutting arc. The circuit is a simple, resistance-loaded connection which limits the current from the power supply to the nozzle during arc starting.

Linde Air Products Co. has devoted the majority of its development work on this project to aluminum cutting applications. To date, aluminum cutting is the only process that is ready for commercial application. However, the company plans to make a thorough investigation of the applications of Heliarc cutting in the general field of metal fabrication. The results of preliminary investigations indicate that the process will work on many nonferrous metals in addition to aluminum. However, Linde stressed that at this time it could make no recommendations for Heliarc cutting with materials other than aluminum.

Even without further development, the use of Heliarc cutting in the aluminum industry is expected to result in increased quality and production in nearly all types of sheet and plate stock forming.





Above—*Schematic of Heliarc cutting operation.*

Left—*Machine mounted cutting installation.*

Western Electric Co. Warns Copper Industry

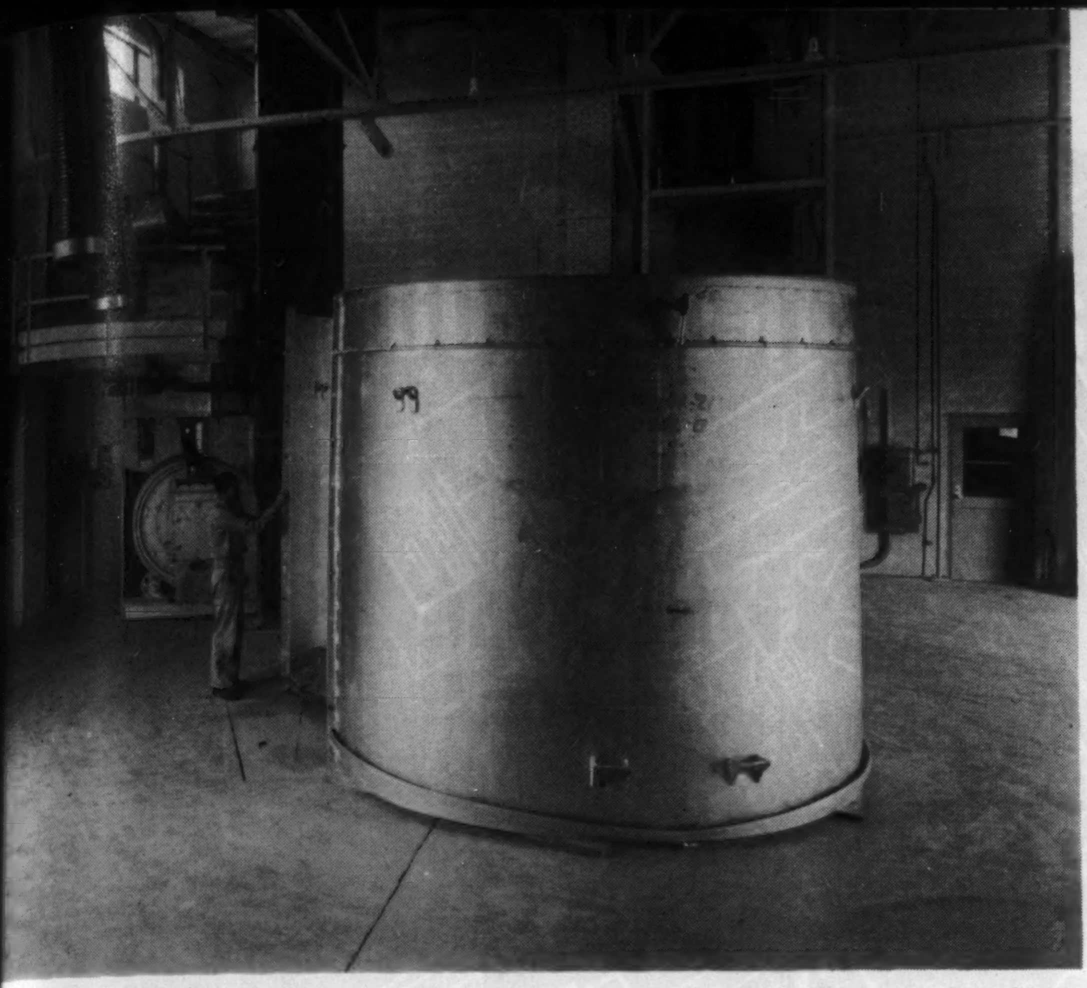
At the height of the copper price spiral, Western Electric Co. let go with a jarring roundhouse punch at copper that probably had more to do with the almost immediate leveling and subsequent drop in scrap and custom smelted copper prices than any other factor.

Western Electric, supplier to the giant complex of Bell Telephone Companies throughout the country and one of the nation's top copper consumers, announced bluntly that copper prices had caused it "to move ahead with a definite engineering development program looking toward the substitution of aluminum in its manufacture of telephone cable".

Pointedly, the announcement warned that Western Electric was setting up initial facilities to develop suitable processes for quantity production of aluminum conductors for certain sizes of telephone cable, and that the program "will be stepped up by converting more facilities now used for drawing copper wire to the extent dictated by economic and supply situations".

Western Electric made it known that its decision to undertake the aluminum substitution program was influenced by mounting concern over increasing copper prices; disruption of production schedules caused by recurrent shortages; and the success it has had in recent experiments with aluminum wire. Besides relieving the company's dependence on one metal, the aluminum substitution program will result in material cost savings based on current price levels. Copper, at the time of the announcement, was selling at 258% above 1946 prices. The rise in aluminum prices during same time was 63% and its price has not been subject to such wide fluctuation as copper.

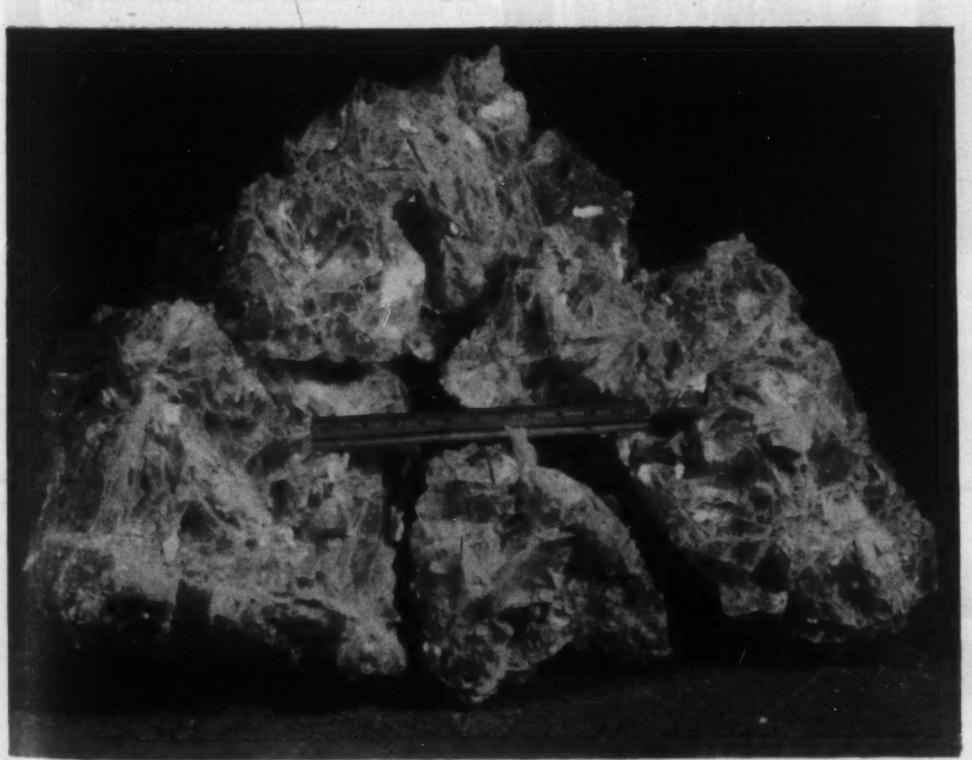
Western Electric also announced that it had solved, to its satisfaction, problems of splicing aluminum wire as well as other installation difficulties related to substituting aluminum for copper.



Mica furnace walls *are put in place over pit in floor. In case of accident, hot melt will drop into cement-lined hole.*

Inside this sintered mass *of raw material is the crystallizing melt. Raw material acts as both insulator and crucible.*

More Synthetic Mica from New Plant



Crystalline synthetic mica *from one of the first melts at the synthetic mica plant.*

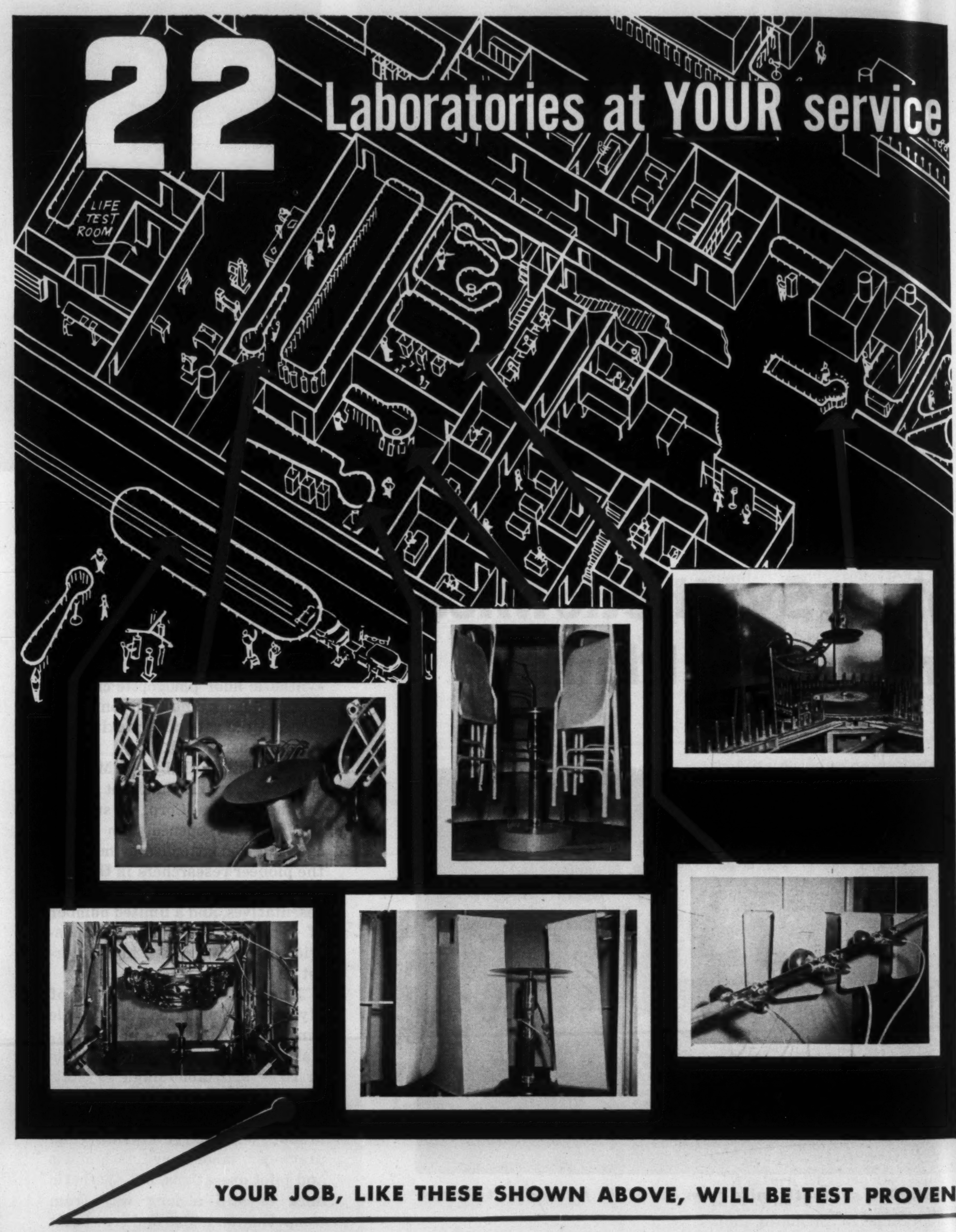
Synthetic Mica

Synthetic mica is officially out of the laboratory. The first plant devoted exclusively to the production of commercial quantities of synthetic fluor phlogopite crystals is now turning out ten-ton batch melts at the rate of approximately one melt per month.

The plant, built by the Mycalex Corp. of America and set up as Synthetic Mica Corp., a subsidiary, formally opened with an inspection tour attended by many of the pioneer researchers in the field of synthetic mica, government representatives, and a limited number of representatives of the industries that have shown high interest in synthetic mica products.

Jerome Taishoff, President of Mycalex, emphasized that while synthetic mica is now in commercial production, it is not available in large splittable single crystals for commercial use. The larger melts from expanded facilities produce more large crystals than previous laboratory techniques and pilot operations, but synthetic mica is still a long way from competing on a size and cost basis with natural India micas. For the present and near future, synthetic

(Continued on p. 239)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under simulated production conditions to determine cost-saving benefits and other advantages. Ransburg also maintains other test facilities in Los Angeles, London, England; Bad Hersfeld, Germany; Paris, France and Sydney, Australia.

DESIGNING WITH ALUMINUM

NO. 16

This is one of a series of information sheets which discuss the properties of aluminum and its alloys with relation to design. Extra or missing copies of the series will be supplied on request. Address: Advertising Department, Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

A WELDING PROCESS IS AVAILABLE FOR EVERY PRODUCT USING ALUMINUM

Good weldability of aluminum alloys reduces the cost and improves the quality of the fabricated product.

The reliability of aluminum welds has been demonstrated by years of service in many applications. Still further developments in welding to improve the weldability of aluminum alloys have been as phenomenal in recent years as the growth of the aluminum industry itself. It is now possible to weld both heat treatable and non-heat treatable aluminum alloys. In addition, several new weldable, high strength alloys have been developed. Of equal importance are the new welding processes currently being adopted to extend the range of weldable alloys and to reduce the cost of welding. As a result of these developments, aluminum can be readily and economically welded.

Welding Processes

Spot welding of aluminum has been used for many years and continual improvements have made the process an important factor in aluminum sheet product fabrication. Pressure welding, one of the oldest methods known for joining metals, is a newcomer in aluminum fabrication. However, it holds intriguing possibilities for new applications (Fig. 1).

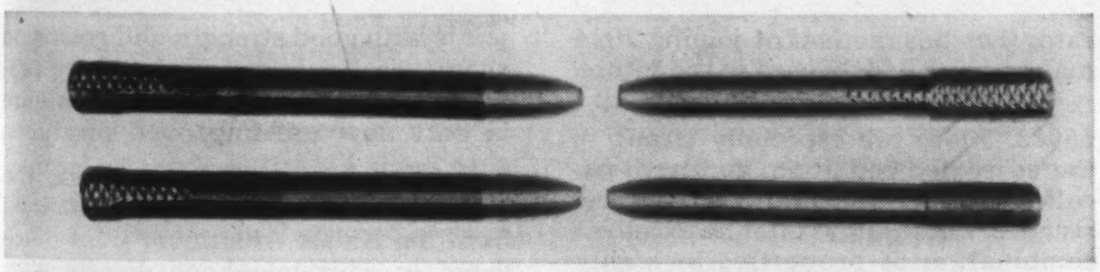

Fig. 1—Pressure welded tensile test specimen of annealed copper to 1100 aluminum 3/8" diameter rod. Fracture occurred in the aluminum with 100% joint efficiency.

Gas welding and brazing, metal arc and carbon arc welding are all suitable for joining aluminum alloys, if the proper fluxes and filler metals are used. However, two newer welding processes are admirably suited for welding aluminum.

Inert gas tungsten arc welding (TIG). This process is an important aluminum joining method. In TIG welding an arc is drawn between the work and a non-consumable tungsten electrode in an atmosphere of argon or helium. No fluxing is required but filler material may be necessary depending on joint design. Table I shows typical welding conditions for tungsten arc welding of aluminum. TIG welding is a relatively cheap method which consistently produces high quality welds with good mechanical properties. With this welding process, flux contamination is eliminated as a source of corrosion. Welding can be performed in flat, vertical, and overhead positions by the TIG process, and distortion is minimized by the high heat input and welding speeds employed. For economy of operation, this process is recommended for sheet material thinner than ¼", although it can be used for welding fairly thick aluminum alloy plate.

TABLE I

TUNGSTEN INERT GAS ARC WELDING (TIG) CONDITIONS

Sheet Thickness	Current Amps' a-c	Wire Consumed Lbs/100 ft of Weld	Welding Speed in/min/pass	Argon Gas Flow (cfh)	No. of Passes	Diam Tungsten	Filler Rod Diam	Gas Cup Diam (in.)
1/16"	80-170*	1/2	12	16-20	1	1/16-1/8"	3/32"	3/8-1/2"
1/8"	150-250*	2	12	20-25	1	1/8-3/16"	1/8"	1/2"
3/16"	180-320*	4	12	20-30	1 or 2	1/8-3/16"	3/16"	1/2"
1/4"	250-350*	9	10	25-35	2	3/16-1/4"	3/16-1/4"	1/2-5/8"

*Using Cooled Backup Bar

Inert gas metal arc welding (MIG). MIG welding is the most important development in recent years to extend and improve the weldability of aluminum. Here an automatically fed filler wire is used to draw an arc to the base plate in a shield of inert gas. As in TIG welding, no flux is required. One of the important advantages is that relatively unskilled labor can be used to operate the equipment. With a minimum of training, operators can make sound welds, at high speeds. Because no flux is used, there is no problem of corrosion by flux residue. Distortion, cracking and similar welding problems are minimized by the high heat input and welding speeds. Table II shows typical MIG welding conditions. This process is used for welding alloy sheet thicker than ⅛" (Fig. 2), and joints in material as thick as 4" have been made successfully.

Factors Affecting Weldability of Aluminum Alloys

Weldability of aluminum alloys depends on the product, service conditions, the alloy itself and on the welding process to be used.

The aluminum surface oxide film is the most outstanding characteristic influencing the welding of aluminum alloys. Generally, this film is one of the most desirable features of this metal. However, in aluminum welding it is

PLEASE TURN TO NEXT PAGE →

TABLE II

TYPICAL INERT GAS METAL ARC WELDING (MIG) CONDITIONS

Sheet Thickness	Current Amps — a-c	Wire Consumption Lbs/100' of Weld	Welding Speed in./min/pass	Argon Flow (cfh)	No. of Passes	Electrode Diam	Arc Volts	Wire Speed in./min
3/16"	170	4	24	50	1	3/64"	22	230
1/4"	200-250	8	24	60	1 or 2	1/16"	24-28	160
3/8"	240-300	16	24	60	2	1/16"	25-29	260
1/2"	250-320	30	17	60	2	3/32"	25-30	130

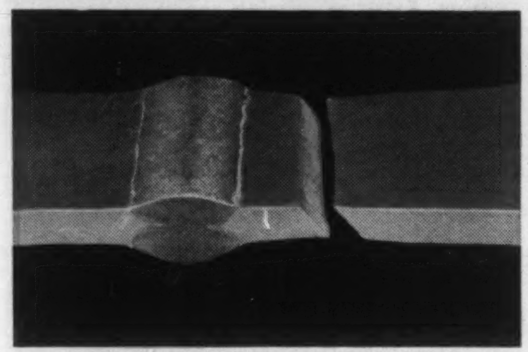

Fig. 2—Tensile specimen of MIG weld in 5086 alloy ¼" plate. Fracture occurred in parent metal at 40,000 psi with 15.7% elongation.

necessary to eliminate its effect. One method is to use a flux which dissolves and carries the oxide film away. In pressure and spot welding, the metal is cleaned so that the thin oxide film breaks up during welding. A third method of removing the oxide is by the action of the arc in the inert gas metal arc welding processes.

Thermal and electrical conductivity are also important in aluminum welding. Because aluminum alloys conduct heat and electricity much better than does steel, much higher currents must be used in resistance and arc welding them. Despite the low melting point of aluminum alloys, aluminum welding requires as much heat input as steel. Aluminum's high coefficient of thermal expansion accentuates internal stresses and warpage, which are also affected by the rate and amount of heat input. Consequently, high welding rates are more economical because expansion and distortion are minimized and less energy is lost.

Where structural strength requirements are high, porosity and crack sensitivity may be encountered. Welding processes and materials are now available for making welds that are consistently nonporous and crack-free. It is particularly important to use clean, dry sheet or plate, suitable filler metal, proper joint design and correct welding procedure.

Except in pressure welding, the welding operation results in fusion bonding two wrought or cast products with cast metal. It is important to recognize that weld metal is a casting and that filler metals must be selected which will combine with the parent metal to form strong, ductile weld deposits. Table III lists recommended filler metals.

TABLE III

RECOMMENDED FILLER ALLOYS FOR WELDING ALUMINUM ALLOYS

Base Plate	Filler Alloy Recommended
1100 3003 3004	1100
6061 6063 6066	4043, X5356, 5154
5052 5254 5086 5083	X5356
2024	2024, X5356

Weldable Alloys

Practically all aluminum alloys can be welded by one of the above processes. Some alloys are more suitable for welding than others. Good welds can be made in the low strength non-heat treatable alloys (1100, 3003, 5005, 5052, 5050) with little or no difficulty. Alloys 6061 and 6063 are also widely used for making strong welded structures by any of the standard processes. Where post-weld heat treatment is possible, joint efficiencies approaching 100% can be obtained. Alloys such as 2024 and 7075 are used in spot welded products. Although arc welded applications of these alloys are rare, recent use of 2024 alloy in arc welded structures, with or without a post-weld heat treatment, indicates that this method of joining 2024 may be more widely used in the future.

TABLE IV

COMPARISON OF TYPICAL MECHANICAL PROPERTIES OF TIG OR MIG WELDS IN ALUMINUM ALLOYS 5083, 5086, 6061, 5052 AND 2024

(Transverse Specimens, Weld Beads Not Machined Off)

Alloy and Temper	Filler Wire	Condition*	Tensile Strength psi	Yield Strength† psi	Elongation % in 2"
5083-H113	X5356	A.W.	42,500	22,000	12.0
5086-H112	X5356	A.W.	39,800	21,000	12.5
5052, 1/4H	4043, 5052, X5356	A.W.	28,000	14,000	15.0
6061-T6	4043	A.W.	30,000	21,000	8.5
6061-T6	X5356	A.W.	32,500	21,000	9.0
2024-T3	2024	A.W.	40,000	20,000	4.0
6061-T6	4043	H.T.	44,000	40,000	5.0
2024-T3	2024	H.T.	54,000	45,000	4.0

*A.W., as welded. H.T., solution heat treated and aged after welding. †At 0.2% offset.

The new non-heat treatable alloys (5083, 5086) are especially strong in the as-welded condition, and have excellent formability and corrosion resistance. These alloys offer an excellent combination of properties in highly stressed welded structures for which they are already being used.

Properties of Welded Joints

Heat applied in the welding operation melts the base plate and filler material in all the welding processes used for joining aluminum, except pressure welding. This heat also anneals the parent metal near the weld. A good general rule for calculating the strength of welded joints is to use the properties of the annealed base plate as design criteria. Some joints are stronger than the annealed parent metal, so that with sound welds and with the beads intact, tensile fractures occur at the fusion line or in the annealed zone adjacent to the weld bead. Table IV shows typical properties of welded joints and illustrates the advantage of using 5083 and 5086 where high strength in the as-welded condition is desired. This further shows the improvement which can be obtained in 6061 welded structures which are heat treated after welding to produce high yield strengths.

The use of sound, economical welded joints with good strength and corrosion characteristics is one of the many reasons for the growing use of aluminum in both new and improved products.

Further information concerning the welding of aluminum may be obtained from the Kaiser Aluminum sales office listed in your telephone directory or one of our many distributors. Kaiser Aluminum & Chemical Sales, Inc., *General Sales Office:* Palmolive Building, 919 North Michigan Ave., Chicago 11, Illinois; *Executive Office:* Kaiser Bldg., 1924 Broadway, Oakland 12, California.

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One point of view

No-good goods are plentiful

Recently the *Wall Street Journal* summarized in an article the complaints which many of us have about the products we buy and use every day. Reporters for that paper covered a New York suburban area to try to bring into the open some of the grumbling we all hear.

The gist of the whole matter is this: Goods such as automobiles, television sets, washing machines and the like are expensive. When we buy them, we expect quality. If something goes wrong, we expect service. Today many of us get neither. Ask any owner of a new car if he has any complaints—but do so only if you have a half-hour to listen. It doesn't seem to matter what make of product is involved, the old standard names are just as bad as any newcomers, it seems.

It might seem strange to write of these complaints on the pages of an engineering magazine, but there is a connection. Most of the complaints we know of have to do with poor materials or the failure of parts due to improper use of materials.

As most of us, know, there are good materials for most of the needs of everyday life. If expensive products fail too early, those who selected and applied the materials must be at fault. Either they don't know as much about their materials as they should, they failed to test the materials properly or they are deliberately using less satisfactory materials in an attempt to shave costs.

If the latter is the cause, it is an extremely short-sighted approach because there are many ways of reducing costs which do not involve cheapening the product. We have pointed out some of these methods editorially from time to time. Too, farsighted companies are spending considerable time and effort to improve quality while lowering costs, or at least reducing costs without reducing quality by the more intelligent use of materials.

Both the buyers and the sellers of materials should make certain that every use of a material is the best one possible. If they don't, irrepairable damage will be done in which everyone will be a loser.

T. C. Du Mond

Fluorocarbon Dispersion Coatings

- ► *What they are*
- ► *What they can do*
- ► *Where to use them*

by Gene Bartczak

Over the past few years, fluorocarbons have become available as coatings. These versatile finishes are finding acceptance in many fields of industry because of their unique chemical, physical and mechanical properties.

Non-stick, non-toxic *characteristics of Teflon are used here by coating cookie rolls to reduce rejects and produce sharper patterns.*

(E. I. du Pont de Nemours & Co., Inc.)

■ The unique combination of chemical, electrical, thermal and mechanical characteristics of fluorocarbon plastics is available in the form of coatings which can be applied to metallic or nonmetallic surfaces and dried or fused to provide desired physical characteristics. There are two basic types of fluorocarbon resins, both of which are being supplied as coating materials. Polytetrafluoroethylene is being commercially produced only as Teflon, by du Pont. Polychlorotrifluoroethylenes, known generically as chlorofluorocarbons or chlorinated fluorocarbons, are being supplied by M. W. Kellogg as Kel-F, by Acme Resin as Polyfluoron, and by Bakelite as Fluorothene. The types of proprietary coating formulations available are outlined in an accompanying box.

Two classes

There are two general classes of fluorocarbon coatings available today: the temporary (air-dried) type and the permanent (fused) type. Both can be applied by brush, dip or spray methods and have similar chemical and thermal characteristics. The finished coatings, however, differ greatly.

Temporary or air-dried coatings consist of lower molecular weight members of the polychlorotrifluoroethylene family, namely oils, greases and waxes which are applied from solvent solutions. The protective film is formed at room temperature by evaporation of the solvent. Since no heat is used to fuse the fluorocarbon particles, resulting coatings can be dislodged relatively easily. Densities of these coatings range from 1.8 to 2.0 gm per cc and viscosities range from 5 to 1125 centistokes to suit application methods. They readily wet metallic surfaces, and can be used on rubber and plastics with no significant reaction between coating and coated material at room temperature, and with variable results at elevated temperatures. Applied from solvent solutions and being of a temporary nature, these coatings are not recommended for use in contact with other solvents, at high tempera-

DISPERSION SPECIFICATIONS

Coating Material	Resin Content %/wt	Vehicle	Viscosity	Coverage, sq ft/gal (1 mil thick)	Weight, lb/gal	Shelf Life	Remarks
TEFLON							
Steel Primer	46			475	11.5		Resin particle size: 0.5 micron
Aluminum Primer	48			496	11.5	10 mo at 40 F 1 mo at 70–80 F	Reduction: with distilled water or acetone for corrosion-resistant coatings
One-coat Enamel	48			505	11.8		
Clear Finish	48	Aqueous	Spray & Dip	473	11.0		
White Enamel	45			440	11.0		
Gray Enamel	45			440	11.0	1 yr at 70–80 F	
Red Enamel	42			400	10.6		
Black Enamel	41			385	10.4		
KEL-F							
N-1	35	Xylene type	32–34 sec (Zahn)	—	—	3 yr	Resin particle size: 1-20 microns (avg: 3 microns)
N-2 (dip)	40	Amyl acetate type	9–10,000 cps	330	11.5–12.2	Probable: Indefinite	Reduction: with acetone, amyl acetate or xylene
Nw-25-TR (spray)	40	Xylene type	32–34 sec (Zahn)	265	11.5–12.2		NW-25-TR has lower coverage due to wax content
POLYFLUORON							
Paste	40		1800–1980 cps	—	11.1		Resin particle size: approx. 3 microns
Primer #150	—	Proprietary chlorinated hydrocarbon	84–88 cps	—	7.8	Indefinite	Reduction: Polyfluoron dispersant, methyl isobutyl ketone
Suggested: Dip	35		1050–1100 cps	340	10.0		
Spray	30		290–315 cps	225			
Dip	25		60–80 cps	—	8.8		

tures, or with high velocity gases and liquids.

Permanent, or bake-on type fluorocarbon coatings, are dispersions or suspensions of finely divided high polymer resins of either the tetrafluoroethylene or chlorinated fluorocarbon type in an aqueous or spirit vehicle. They are applied by brush, dip or spray and fused at high temperatures to provide optimum durability and chemical, thermal and electrical resistance. In addition, they have unusual non-sticking characteristics and inertness to fungus attack even at 100% relative humidity. The remainder of this article will deal mainly with the permanent type coatings.

Types of dispersions

Dispersion formulations have resin contents which vary from 25-50% by weight. Teflon dispersion particles are about 0.5 microns in diameter, while those of chlorinated fluorocarbons average about 3 microns in diameter. Smaller particles fuse more rapidly and larger particle size presents some problems in preventing thermal degradation. Small particle size allows formulation of coatings with high solids content, yet low viscosity. Two general types of vehicles are used for the two types of dispersions: an aqueous-acidic for Teflon and an organic spirit such as xylene, amyl acetate, or chlorinated hydrocarbons for the chlorinated fluorocarbon resins.

Teflon dispersions presently available consist of two primers, a clear finish, a one-coat enamel and four colored enamels. All but the one-coat enamel must be applied over primers. If lower viscosities are required, user can reduce dispersions with up to 20% distilled water, or with acetone where higher impermeability is required.

The Teflon steel primer provides excellent adhesion to ferrous metals, nickel, chromium and its alloys, aluminum, sand-blasted glass and porous ceramics. The primer particularly designed for aluminum alloys also gives good results on porous ceramics, and only fair results on ferrous metals. Teflon one-coat enamel, combining primer and finish coat, is used for rapid application of relatively thin (0.7 mil) coatings for anti-stick and high temperature service. A black enamel is compounded with coalescing agents to permit application of relatively thick films (up to 2 mils per fusion) without mudcracking. The Teflon clear finish provides optimum chemical, electrical, thermal and wear resistance when applied from an acetone-reduced dispersion. It is usually specified as a top coat in almost all Teflon coating systems.

Five chlorinated fluorocarbon dispersions are available. A straight resin-vehicle formulation (N-2) of moderate viscosity is designated for dip and brush coating. For spray application a balanced mixture of the dip formulation and components of chlorinated fluorocarbon waxes and oils

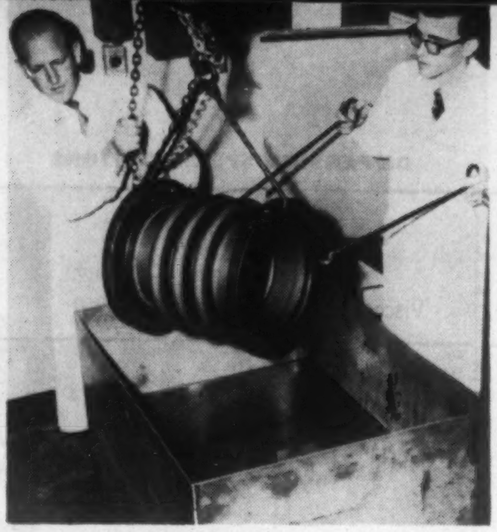
(NW-25-TR) reduces spray losses, provides better adhesion to substrates and promotes rapid fusion of particles. Additives are mostly volatilized during fusion. A resin bank dispersion (N-1), used to enrich other dispersions, or for formulating new ones, is based on an amyl acetate solvent and may be reduced with additional amyl acetate or methyl isobutyl ketone. Dip dispersions may be reduced with xylene or acetone. Reduction with acetone provides formulations with quick-setting characteristics for dipping small objects or coating interiors of small tubing. Chlorinated fluorocarbon formulations, though quite fluid, are thixotropic. Brush marks can be leveled by mechanical vibration immediately after application.

Properties

Fluorocarbon coatings have essentially the same physical properties as parts molded of the resins. Teflon coatings have fair impact resistance but will deform permanently if thickness is sufficient to allow flow. In some cases they tend to cavitate and chip. Teflon's waxy, self-lubricating characteristic is advantageous in bearing and wear surface applications. Kel-F, Polyfluoron and Fluorothene coatings are characterized by high tensile and compressive strengths, good elongation and excellent abrasion and wear resistance.

Chemical resistance — Chemical resistance of fluorocarbon resins is unexcelled by any other plastics resin. Teflon has no known solvent and resists attack by most chemicals and solutions of chemicals at temperatures up to their boiling point (with exception of molten alkali metals, fluorine and chlorine trifluoride). Kel-F and other polychlorotrifluoroethylene resins closely approach Teflon in chemical resistance.

Although Teflon itself is superior in chemical resistance, in fused coatings of 4 mils or more, chlorinated fluorocarbons provide a higher degree of protection to base metal because Teflon coatings have intermolecular permeability due to release of water during fusion. Coating protection is improved by deposition from a 5-7% acetone-reduced dispersion. Even greater protection is provided by undercoating the finish with six 1-mil coats of clear Teflon primer.



***Dipping and fusing** a Kel-F coating on high-pressure expansion joints for corrosive petroleum lines allows the joints to be made of cheaper, lighter metal.* (*The M. W. Kellogg Co.*)

Since adhesion of fluorocarbon coatings is purely mechanical, permeability is doubly important. A corrosive, once introduced, can undermine the coating and destroy its effectiveness. Teflon coatings usually provide poor protection when exposed at around 200 F to mineral acids such as nitric and hydrochloric in liquid and especially in gaseous phase. They provide good to fair protection against 20% hydrochloric and nitric acids at room temperature. Also good to fair protection against 73% caustic, 95% sulfuric acid and toluol at 200 F.

Chlorinated fluorocarbon coatings are less permeable to liquids and gases than Teflon, when molecular weight is kept high. They are unaffected by solvents, ozone, sunlight and strong bases and acids including fuming oxidizing acids. Some unsaturated and halogenated hydrocarbons, ethyl ether, anhydrous chlorine, and molten alkali metals affect chlorinated fluorocarbons in varying degrees. Swelling in the presence of some solvents does not necessarily mean the coating material will not be effective in protecting base materials from those solvents.

Teflon has the best anti-stick properties of all fluorocarbon coatings. No materials such as textile size, glues, inks, paints, greases, meats, baked goods, candies, waxes, rubber or casting resins will adhere to it. This characteristic coupled with high temperature resistance has given Teflon priority in applications such as coatings for jaws of heat sealing machines. Abrasion resistance is adequate, except for moderately heavy service where its soft waxy surface may prohibit its use. Its low coefficient of friction makes the material virtually self-lubricating.

Chlorinated fluorocarbon coatings have anti-stick characteristics similar to those of Teflon, except for the most tacky substances and the higher service temperatures. Taber abrasion ratings of 0.0117 to 0.0131 gm per 1000 cycles indicate their superior abrasion and rubbing resistance.

Temperature resistance—Teflon coatings will withstand continuous service at 480-550 F and intermittent service up to 572 F, as compared with continuous service limitations of 390 F, and intermittent service maximum of 420 F for chlorinated fluorocarbons. Safe temperature limit from the standpoint of evolution of toxic fluorine compounds, however, is 450 F for Teflon and 572 F for chlorinated fluorocarbons. In regard to low temperature characteristics, 10 mil fused fluorocarbon coatings are capable of taking 180 deg bends around a 1/8-in. mandrel at −320 F without failure. The coatings are nonflammable, and are unaffected by open flame until their softening point is reached, at which time degradation begins.

Electrical characteristics—High polymer fluorocarbons have outstanding dielectric characteristics at low to very high frequencies over a wide range of temperature. Zero water absorption and nonwetting characteristics improve their insulating qualities by reducing surface arcing and corona losses.

Major electrical uses for Teflon coatings are in glass fabric insulators where power factor remains less than 0.25% over the entire range from 60 to 1,000,000 cycles. Volume resistivity at room temperature is greater than 10^{15} ohm-cm, even after prolonged immersion in water. Similar results are obtained with the material when used for wire insulation in coating thicknesses of more than 3 mils.

Though chlorinated fluorocarbon coatings cannot match the extremely low and consistant power factor of Teflon, they are equivalent in short-time dielectric strength with approximately 530 volts per mil, and are superior in volume resistivity with values of 10^{18} ohm-cm.

Materials that can be coated

Materials to which fused fluorocarbon coatings are to be applied must be capable of withstanding the relatively high temperatures needed to fuse the resins. Chlorinated fluorocarbons are fused at 475-515 F, while Teflon coatings are fused at 650-750 F. Some Teflon coatings have been applied at a low of 350 F, and chlorinated fluorocarbons at temperatures as low as 420 F. Most ferrous and nonferrous alloys, glass, glass cloth and ceramics as well as plated metals can be coated. Surface irregularities must be minimal since dispersions will not fill them by capillary action, but will bridge, possibly causing failure during service. Metals such as copper-base alloys with surface activity at elevated temperatures may cause peeling of coatings due to oxide formation. Copper-base alloys also may catalyze degradation of chlorinated fluorocarbon coatings. Tin, nickel, silver, tin-lead alloys or cadmium plating reduce this activity.

Application techniques

All surfaces to be coated must be degreased, free of dust or organic matter, then lightly sandblasted or otherwise roughened to provide a good tooth for the coatings. Since fluorocarbons are chemically inert, their adherence is strictly mechanical, though

PROPERTIES OF FUSED FLUOROCARBON COATINGS

Property	Polytetrafluoroethylene (Teflon)	Polychlorotrifluoroethylene	
		Kel–F	Polyfluoron
Specific Gravity	2.1–2.3	2.1	2.12
Hardness, Shore	D–55	D–77	—
Adhesion, lb pull on 1–in. strip	10.3 (over primer)	5–10 Cannot be peeled off primers.	5 without primer. Cannot be peeled off primers.
Tensile Strength, psi, 77 F	1500–2000	4500–5000	5890
Elongation, %	100	150–200	25–87
Impact Strength, Izod ft-lb/in. notch at 77 F	4.0	3.5	1.52
Compressive Strength, psi at 77 F	1700	32,000–80,000	—
Frictional Properties, 2-lb load /½-in. slider	Steel-Teflon = 0.11 Teflon-Teflon = 0.04	Steel-Kel-F=0.70 Kel-F-Kel-F=0.55	—
Abrasion Resistance	2160 gms abrasive/mil (Bell Abrasive Tester)	0.0131 gm/1000 cycles (Taber)	0.0117 gm/1000 cycles (Taber)
Thermal Conductivity, 10^{-4} cal/sec/cm²/C/cm	6	1.4	1.4
Thermal Coefficient of Lin. Expansion, 10^{-5} in./in./C	10	4.5–7	5.1
Resistance to Heat, F, Continuous	480–550	390	300
Short Time	572	420	350
Burning Rate	nil	nil	nil
Moisture Absorption, %	0.00	0.00	0.00
Water Vapor Transmission, gm/100 in. ²/24 hr	—	0.00	0.00
Dielectric Strength, Short Time, v/mil	400–500	530	600
Power factor, 60 cycles to 1 mc	0.0008–0.007	0.01–0.012	—
Volume Resistivity, ohm-cm	10^{16}	10^{18}	—
Color Possibilities	Extensive	Unlimited	Unlimited

CHEMICAL RESISTANCE OF TEFLON COATINGS[1]

Virgin Resin	Fused Coatings [2]
Affected by	
(x) Molten alkali metals (x) Fluorine gas (m) Chlorine trifluoride	(m) Nitric acid at 200 F (x) Hydrochloric acid at 200 F Other corrosive solutions
Resistant to	
All known chemicals and solutions of chemicals, including: Fuming oxidizing acids Aqua regia Mineral & organic acids Alkalis Hydrofluoric acid Organic solvents Oxygen Ozone Alcohols Anhydrides Ketones Saturated, unsaturated hydrocarbons	Ammonium sulfate Aromatic, aliphatic hydrocarbons Caustic, 73% at 200 F Diethylene glycol Diphenylamine Hydrogen sulfide Phenothiazine Sulfated higher alcohols Sulfonated oils Sulfur vapor Terpenes Toluol at 200 F

[1] *Since fused chlorinated fluorocarbon coatings have essentially the same resistance as virgin resin due to film continuity, they are not included here.*

[2] *Resistance here is also a function of ability to stop permeation through coating, undermining it.*
m = moderately, x = extremely

some new chlorinated fluorocarbon primers, consisting of Kel-F plus a thermosetting material are claimed to provide a chemical-type bond to metals. Coatings may be pressure sprayed, dipped, brushed or spread-coated on surfaces. After applying, coatings are flashed to prevent cratering or formation of other irregularities during fusion. Polyfluoron coatings are partially dried in closed containers so that fusion takes place in a solvent-saturated atmosphere. Coatings are fused at 480-525 F for chlorinated fluorocarbons, and 650-750 F for Teflon.

Total film thickness which can be deposited lies within the range of standard baked enamels, from 4 to 20 mils, with a theoretical thickness of several times this maximum claimed for Kel-F coatings. Lay-down thickness before fusion is required, varies from 0.4 mils for Teflon primers, to 2 mils for one-coat enamel, to 2-4 mils for Kel-F dispersions, to 10 mils for Polyfluoron. Total thickness of Kel-F films is governed by the total exposure time of the first coat to fusion temperatures. Over-baking results in cracked, brittle films which are impossible to repair and must be burned off.

After fusion, chlorinated fluorocarbon films should be quenched in water or air. Films of this type, cooled slowly to room temperature, become crystalline and opaque, with high tensile strength, but with poor elongation and flexibility. Rapid quenching provides amorphous coatings which are transparent, tough and more extensible, flexible and impermeable to corrosives than slowly cooled coatings.

Rapid quenching of Teflon coatings makes them tougher and more transparent. A higher degree of impermeability is developed in Teflon by cold working fused films with a light sanding or buffing.

Variations in coatings and application techniques—Chlorinated fluorocarbon dispersions for dip coating are supplied at high viscosities for spread-coating glass, asbestos, fabrics, and other material impractical to coat by other means. Fusion time can be reduced from hours to minutes by application of 500 to 1000 psi pressure and heat to the coated material through platens or rollers. Two to three mils per pass are obtainable on heat-cleaned and silane-finished glass cloth, asbestos and other heat-resistant materials.

Teflon materials for application by this method are not available, though finished coated cloths and laminates are. Such deviations from standard constructions as single and double-face coated glass and asbestos cloth and laminates are also produced for application with conventional epoxy and other adhesives.

Unsupported chlorinated fluorocarbon films can be produced by modifying the spray application technique. Coats are sprayed and fused on a highly polished male mold, then peeled off. Two-mil thick diaphragms produced in this manner have lower permeability than equivalent extruded or molded film.

Repair of coatings

Defects and damaged areas in both types of coatings can be repaired by cutting out an area sufficient to provide a good hold for the new coat, and repeating the original application and fusion cycle. Thermoplastic chlorinated fluorocarbon materials soften on heating, and patches of extruded film can be heat-sealed over the defect using a properly shaped iron heated to 550-600 F.

Storage and warnings

Teflon dispersions remain stable for periods of from 1 to 12 mo, depending on conditions. Clear

TYPICAL COATING APPLICATIONS

Teflon Coatings	Chlorinated Fluorocarbon Coatings
Agitator Paddles	Bobbin guides
Bearings	Bus bars
Bread baking pans	Casting molds
Candy molds	Chemical valve linings
Centrifugal pumps	Exhaust fans and blowers
Drum driers	Expansion joints
Dry ice platens	Foam rubber molds, tire molds
Extrusion dies	Heating coils
Feed hoppers	Idler rolls
Glass stopcocks	Laminates
Gluing machines	Magnet wire insulation
Heat sealing units	Metal gaskets
Molding dies	Ribbon blenders
Motor slot liners	Seals for electric cable covers
Pipe and tank interiors	Sight glasses
Printing equipment	Silicone rubber gaskets
Rubber molds	Storage tanks
Snow plow blades	Tank car linings

RECOMMENDED COATING THICKNESS FOR SPECIFIC APPLICATIONS, MILS

Service	Teflon	Kel-F	Polyfluoron
Anti-Stick	0.7–2.3	2–5	3–4
Thermal	0.7–1	—	0.5–1.0
Corrosion (mod)	6–8	>10	4[1]
Corrosion (severe)	8–20	>15	8
Electrical Insulation	3–6	10	5–10

[1] *Plus prime coat*

finishes and colored enamels are stable for one year at room temperature. Primers and one-coat enamels remain stable up to 10 mo at 40 F, and only one month at 70-80 F, and therefore should be refrigerated, though freezing temperatures must be avoided. Acidity of mixtures requires venting of containers at least once a month to relieve pressures, and gentle agitation to re-disperse solids.

Chlorinated fluorocarbon dispersions are stable indefinitely, assuming no major loss of vehicle. Kel-F, for example, has an established minimum shelf life of 3 yr at room temperature.

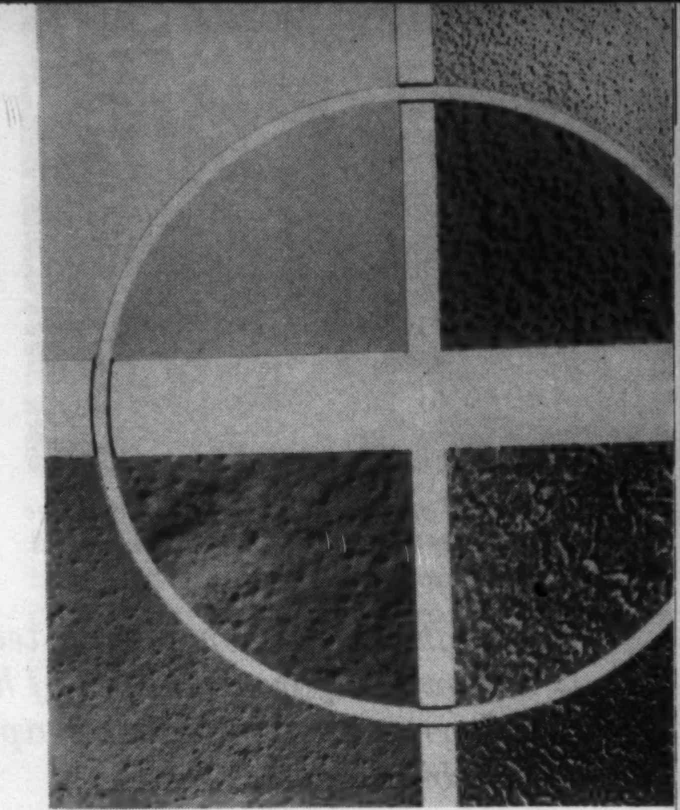
Both groups of dispersions contain materials potentially hazardous to applicators and users. Acidic Teflon dispersions, the spirit vehicle in Kel-F formulations and Polyfluoron's chlorinated dispersant are toxic in varying degrees on prolonged exposure. At above 400 F Teflon gives off minute quantities of gaseous fluorine compounds. At 600 F and above, measurable quantities are given off, followed by evolution of sublimates. At 750 F, total decomposition begins, taking place quite violently at temperatures above 900 F.

At temperatures of 570 F and above, chlorinated fluorocarbon resins evolve traces of halogen acids. Degradation at elevated temperatures yields lower molecular weight polymers rather than monomers, and breakdown is accomplished through molecular scission rather than zippering, which is characteristic of Teflon. In both cases, any volatile fluorine products evolved should be considered potentially hazardous.

Promising future developments

Two chemically-resistant and flexible coatings, based on Kel-F Elastomer are expected to be announced next year. Neither will require high fusion temperatures presently necessary. One is a low temperature oven-curing compound, the other is a lacquer, applied from solvent solutions and air-dried. Both will probably utilize a thermoset primer to improve adhesion. According to preliminary reports, the rubber-like coatings are compatible with other elastomers and provide good performance at temperatures ranging from sub-zero to over 440 F.

Solubility of chlorinated fluorocarbons in selected ketones and other solvents will make a variety of coatings possible. One lacquer, with a resin content of 25% and a viscosity of 45,000 cps is being evaluated in knife coatings on natural and synthetic fabrics and glass fiber. Thin, unsupported films cured at 300 F, show tensile strength values of 2500 psi and elongations of 400-500%. If proven out, these new coatings will add the advantages of rubber to fluorocarbon coatings, as well as allow coatings to be applied to materials which cannot stand the fusing temperatures presently necessary.



***Proper application techniques** are vital in producing sound films. Upper left: spray coating, air dried at 15-20 psi air pressure; upper right: coating dried at too high air pressure; lower left: coating applied too wet, coating craters; and lower right: too heavy intermediate coats cause mud-cracking.* (The M. W. Kellogg Co.)

Where to Buy Which Coating Materials

PERMANENT (FUSED) COATINGS

Polytetrafluoroethylene

Teflon — Two primers for metallic and other types of surfaces; 6 special formulations (4 colored), ready to use for spray or dip application. Source: E. I. du Pont de Nemours & Co., Inc., Finishes Div., Wilmington, Del.

Polychlorotrifluoroethylene (chlorinated fluorocarbons)

Kel-F—A spray and a dip dispersion, as well as a "resin bank" dispersion for enriching the other two or formulating new ones. Source: The M. W. Kellogg Co., Chemical Mfg. Div., Jersey City 3, N. J.

Polyfluoron — A ready-to-use primer for metals, a finish-coat dispersion paste to be diluted by user, and a special dispersant for dilution of both primer and finish coats. Three colors are available. Source: Acme Resin Corp., Forest Park, Ill.

Fluorothene—High polymer resin available in small particle size for user to formulate into dispersions. Formulation recommendations are available. Source: Bakelite Co., Div. of Union Carbide and Carbon Corp., New York, N. Y.

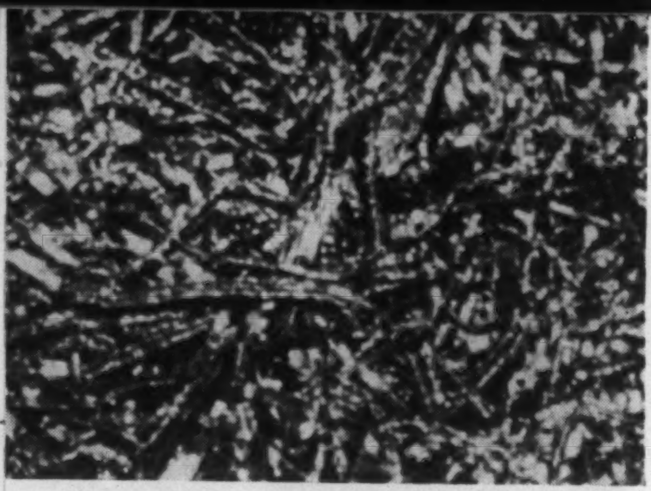
TEMPORARY (AIR-DRIED) COATINGS

Available only in chlorinated fluorocarbon resins

Kel-F—Available as light, medium and heavy oils; waxy oils and hard wax. Soluble in selected solvents. Source: M. W. Kellogg Co.

Fluorolubes — Available as two light oils, two heavy oils, and three greases. Soluble in selected solvents. Source: Hooker Electrochemical Co., Niagara Falls, N. Y.

Halocarbon — Available as two light, two medium and two heavy oils, and four waxes. Soluble in selected solvents. Source: Halocarbon Prod. Corp., Hackensack, N. J.

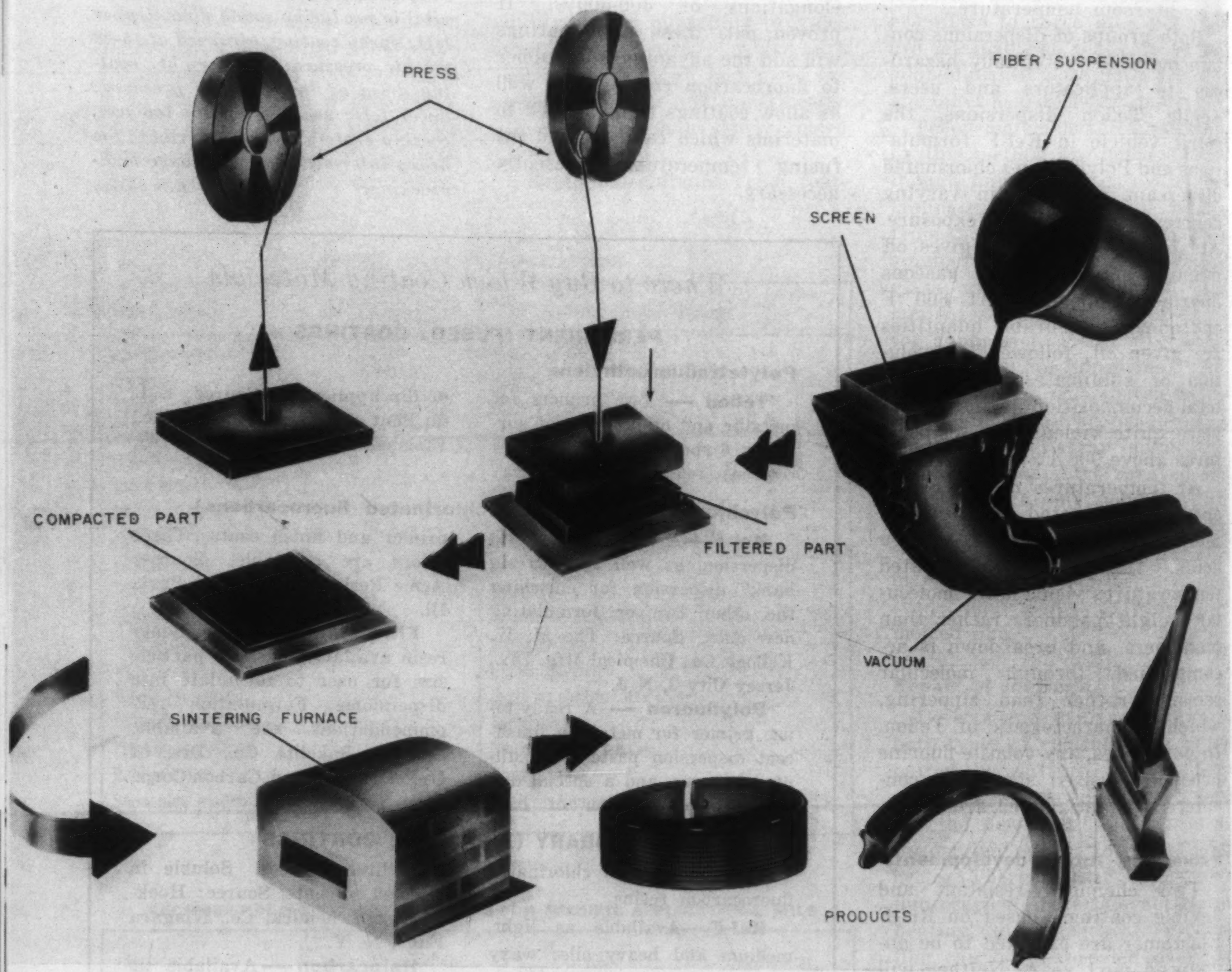


Fiber metal sheet (25x) can be further shaped into complex forms.

Fiber Metals

A New Metal Form

- *High production felting techniques can be used.*
- *Complex porous shapes of high toughness are possible.*
- *Current work suggests applications as filters, airfoils, turbine blades.*


PRESS
FIBER SUSPENSION
SCREEN
COMPACTED PART
FILTERED PART
VACUUM
SINTERING FURNACE
PRODUCTS

Flow sheet shows how metal fibers are processed from a fiber suspension to the finished product.

by **A. G. Metcalfe,** *Senior Metallurgist,* and **C. H. Sump,** *Supervisor, Armour Research Foundation*

■ Fiber metallurgy is a new and unique metal forming technique which provides a production method for forming complex porous shapes.

It has production potentialities because it can employ felting procedures. The paper making industry is an example of a related production process employing this felting procedure. In both cases, a suspension or slurry of fiber is deposited as sheet in equipment such as the Fourdrinier machines. Although no metal fiber plant for felting is in operation at the moment, there does not appear to be any reason why this process should not be applicable to fiber metallury. The combination of felting with rolling would enable a wide range of densities to be produced at the same high speed.

Important improvements in properties of powder metallurgy products can result from fiber metallurgy development. Perhaps the most important application may be in the development of a high degree of toughness in porous or cermet materials where poor impact properties have retarded the utilization of many of these high temperature materials.

How it's done

The raw material for fiber metallurgy parts is wire. The fibers or filaments are made from the wire by a shaving process. In this way fairly continuous strands of metal can be formed. Control of fiber dimensions can be effected by adjustments of the planers. Those metals and alloys that are machinable can be made into fiber, but new techniques are necessary for others. It is expected that as fiber metallurgy grows, new sources of supply will appear for this new market, particularly for the finer fibers.

Fiber metal forms can be made today . . .

- As thin as 0.010 in.
- Rolled to 0.002 in.
- In thicknesses up to 1 in.
- In porosities up to 98%
- In strength up to 35,000 psi

In felting, a suspension of the slurry metal fiber is in contact with a porous master subjected to vacuum. The liquid is drawn away through the master, leaving the mat of fiber on the master surface. One of the advantages of this process is that the master can be of complex shape.

Considerable adjustment in properties can be made by control of such fiber characteristics as length, diameter, kinking, surface roughness, etc. For example, a rough, barbed surface offers opportunity for mechanical interlocking of fibers to strengthen low density bodies. By preferred orientation of the fibers, directional properties can be achieved and greater strength in a given direction obtained.

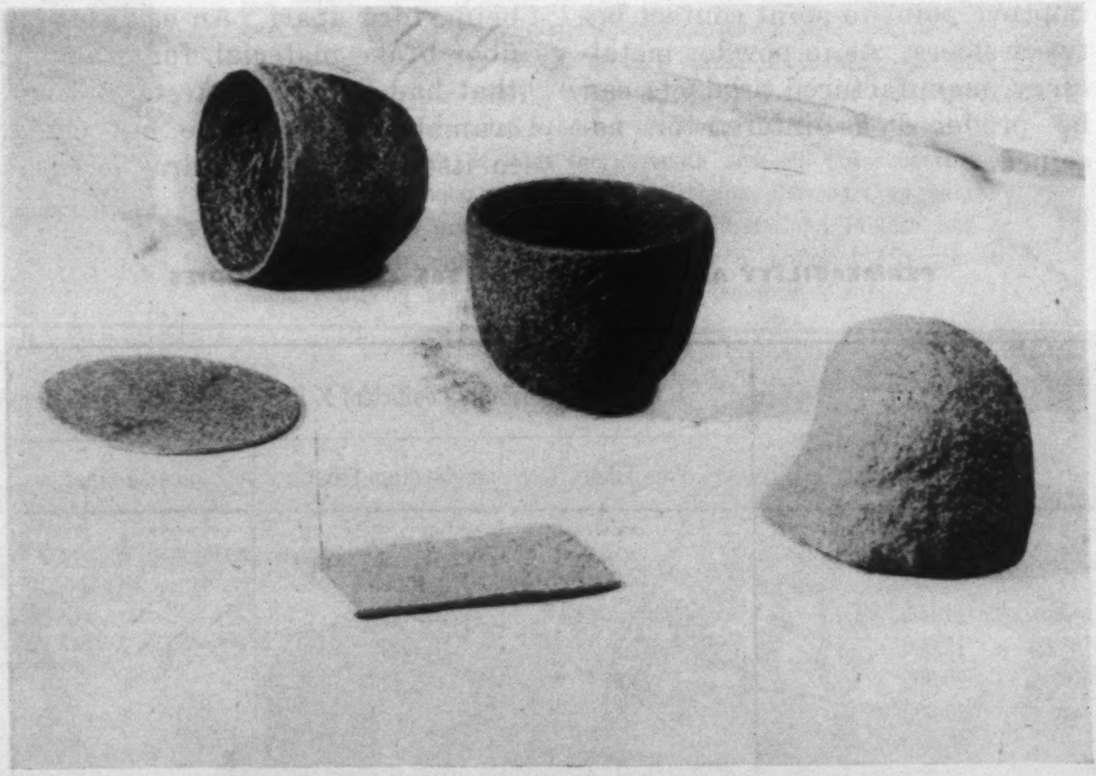
Subsequent handling of the felted metal depends almost entirely on its end use. For high density parts, it can be processed through rolls or in dies in either single or multiple steps. As a sheet material, it can be processed con-

POROSITY AND STRENGTH OF METAL FIBER BODIES

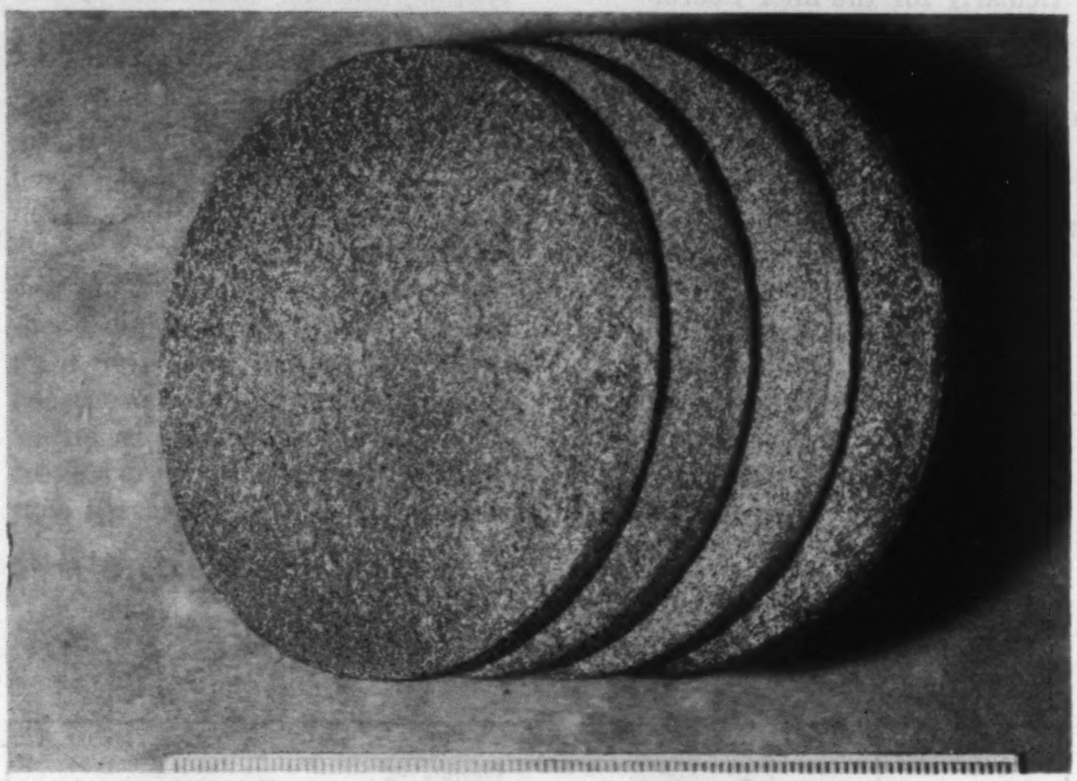
(Preliminary Results)

Ult Ten Str, psi	Porosity, %						
		SAE 430					
	Iron Fiber P,S	Fine P,S	Fine P,S,C,S	Fine Annealed P,S	Fine F,P,S	Medium F,P,S	Coarse F,P,S
5000	—	55	—	—	—	—	—
7500	50	49	—	—	—	54	—
11,000	40	39	—	34	—	40	—
15,000	30	31	—	25	38	34	36
20,000	—	20	—	16	32	28	25
25,000	—	13	25	—	27	24	16
30,000	—	—	16	—	—	21	9

F—Felted *S—Sintered*
P—Pressed *C—Coined*



Felted shapes *shown have been pressed and sintered.*



***Fiber metal disks** are typical of forms that can be produced.*

tinuously from felting, rolling, annealing and sintering. Complex shapes can be compacted hydrostatically, using a rubber sac to transfer pressure to the part.

Higher strengths can be achieved by many of the methods developed for powder metallurgy. For example, ferrous fibers have been copper brazed to achieve greater stiffness. Sintering with a certain amount of liquid phase present can be used also to increase the area of bonding and to improve point-to-point contact between fibers. As in powder metallurgy, manufactured products can be produced as-sintered or as-coined.

Toughness

Improved toughness is one of the important contributions of this new material. It is believed that this toughness is derived from the unique "woody" structure of fiber metal bodies. Studies of the fractured material show that the breaks are not between fibers usually, but rather break across fiber cross-sections.

As might be suspected, this material has a high degree of tenacity. That is to say, it resists being torn apart. An early metal fiber brake material, for example, that had undergone tests, did not crumble and separate but clung to itself in spite of drastic separation of its parts. This property hardly could be achieved by anything other than a fibrous structure.

To show further the effectiveness of the fibers on toughness, an iron fiber unnotched bar of 18% porosity was impact tested. This bar did not break at 25 ft lb, but bent instead. This is in contrast to a powder compact of about the same porosity that broke with a brittle fracture at 2 ft lb. In this instance, the fiber body has shown a tenfold increase in toughness over the powder body. As might be expected, combinations of powders and fibers have shown impact strengths between those shown for either powder or fiber alone.

Potential applications

The work done to date in fiber metallurgy suggests a number of fields where the unique characteristics of metal fiber parts would be useful.

Perhaps the most promising area of potential use of fiber materials is for high-strength, high-porosity components and parts. As the accompanying tables show, relatively high strengths are possible over a wide range of porosities. Porosities up to 98% have been obtained.

The higher strength-to-porosity ratio, as compared to porous metal powder parts, suggests use as a part of air-foils for de-icing systems on aircraft wing edges, or for transpirational cooling.

Metal fibers can also be used to produce skeletons to support lower strength materials, such as plastics, active catalyst masses, active battery masses and friction materials.

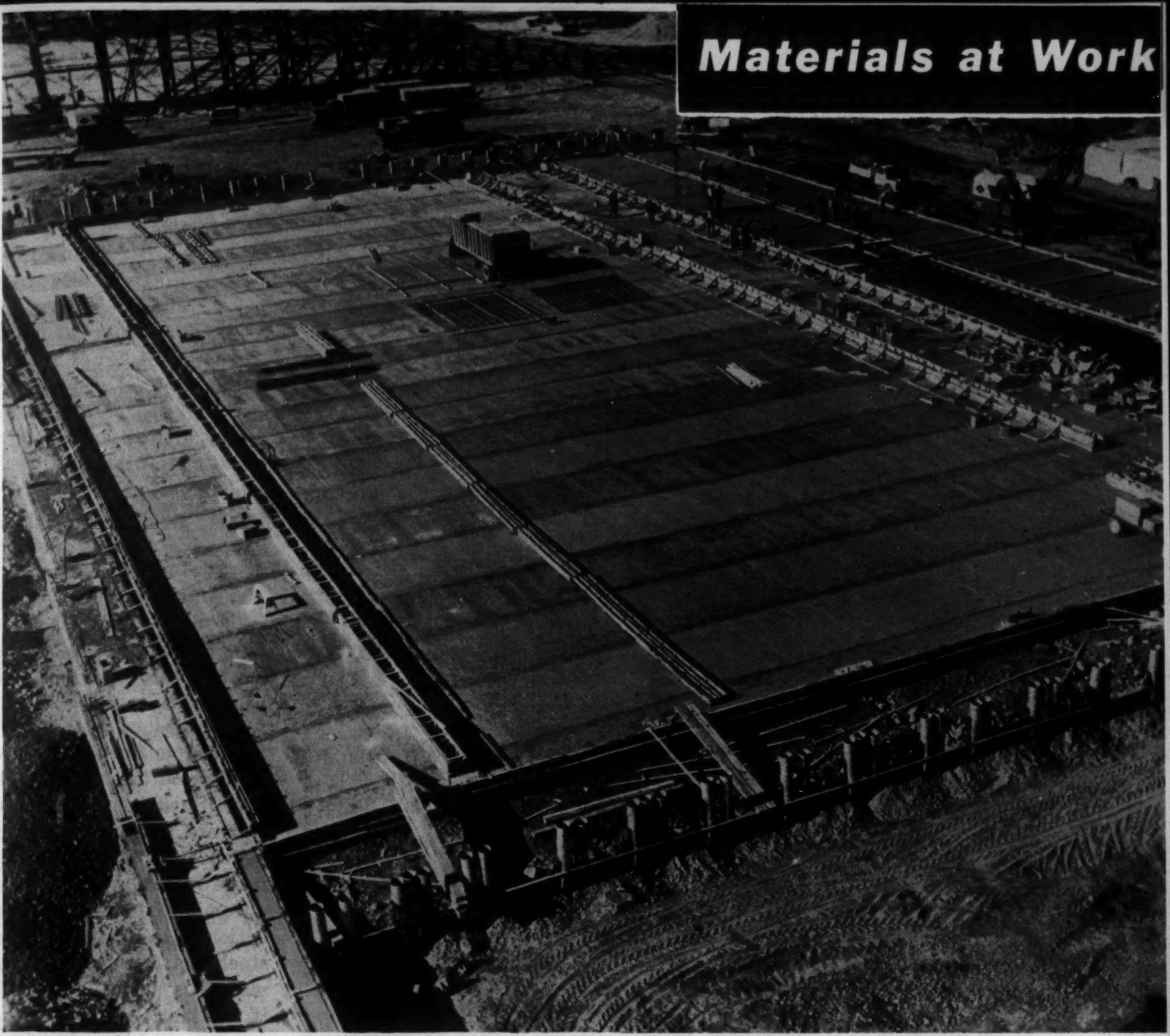
Metal fibers should find use for high temperature service parts. It is believed that incorporation of suitable fibers in metal-ceramic materials and bonded refractory hard metals will increase impact strength and raise the softening temperature.

Further development of the technique should uncover many other useful applications of this new engineering material form.

PERMEABILITY AND STRENGTH OF SAE 430 FIBER BODIES

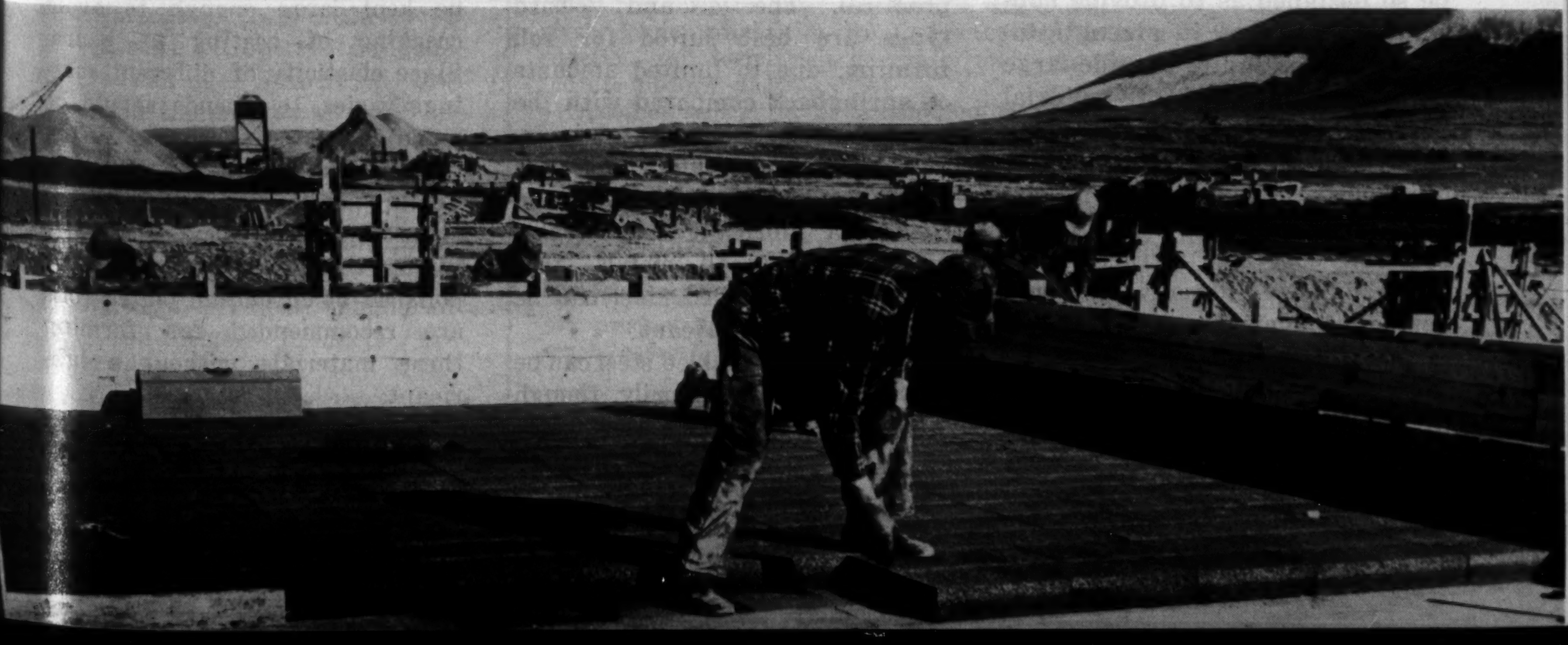
(Preliminary Data)

Ult Ten Str, psi	Permeability Coefficient X 10^{-10} in.^{2}		
	Fine Fiber	Medium Fiber	Coarse Fiber
5000	—	—	—
7500	—	300	—
11,000	—	51	—
15,000	29	32	—
20,000	10	14	24
25,000	2	7	9
30,000	—	3	—
35,000	—	1	—



Glass insulates ground

Four-inch blocks of cellular glass insulation were incorporated in floor slabs of this hangar in Thule, Greenland. Rather than keeping the hangar warm, purpose of the insulation is to prevent hangar heat from melting the permafrost layer of ground under the building. Permafrost is a layer of soil or rock whose temperature has been below freezing for years. When frozen it has good compressive strength. However, after buildings are built, if the permafrost layer is allowed to melt, it loses this strength and will not support the structures. Foamglas, produced by Pittsburgh Corning Corp., has a sealed cellular structure providing good insulation. It also has a compressive strength of over 7 tsi which is sufficient strength to support moving gas trucks, bombers and transport planes.

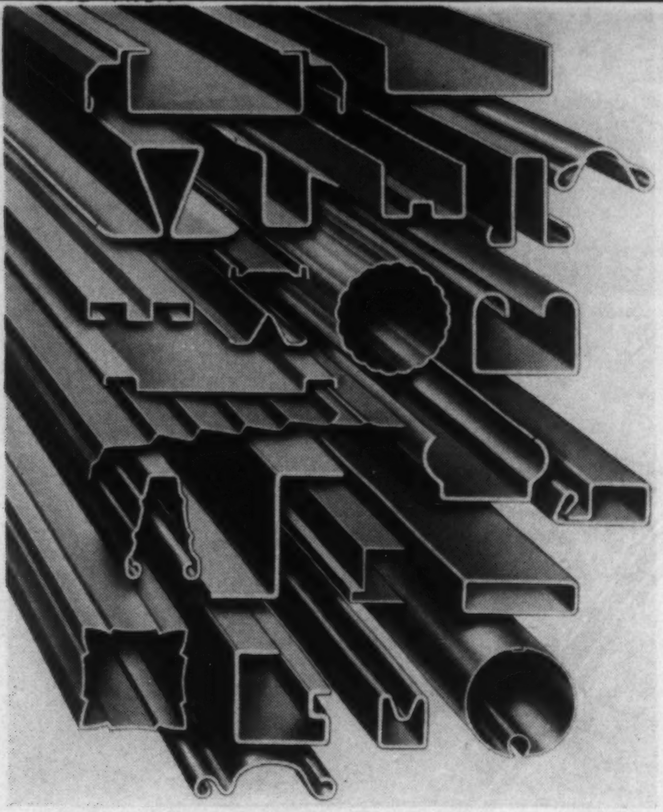


Design flexibility

High production

Close tolerances
and good finish

with . . .



A seemingly endless variety of shapes can be produced by roll forming.

Roll Formed Sheet Metal Parts

Roll formed metal shapes are often seen, but little noticed in a great many pieces of equipment and consumer products. This article tells what metals are available in this form and discusses design considerations, cost factors and applications.

by E. J. Vanderploeg, *Chief Engineer, The Yoder Co.*

■ Roll formed sheet metal parts are well suited for today's mass production techniques. Parts are produced rapidly, in almost any metal with enough ductility to be bent, while at the same time maintaining uniform dimensions and tolerances. Tolerances of ±0.002 in. are commonly held. Shape of rolled formed parts can be so designed as to provide substantial increases in strength-to-weight ratios and to provide large savings in amount of material used. In short, roll-formed parts have high strength, low weight, uniformity, adaptability to assembly by modern welding methods, low cost and attractive as-rolled finish. Normally it would not be economical to consider use of roll formed shapes in quantities less than about 25,000 ft due to the high tooling costs. However, this is a general rule and does not apply in all cases.

Materials

Though practically any sheet metal with sufficient ductility to bend can be roll formed, cold rolled steel is most commonly used. It is easiest to obtain and most economical to use where practical. The ¼- and ½-hard types are best suited for roll forming, due to limited amounts of springback compared with the harder types. There is a minimum of pickup and scuffing between cold rolled steel and the rolls and though a lubricant is advisable when forming all metals, thin gages of cold rolled steel can be run without a lubricant.

Hot rolled unpickled steel can be roll formed satisfactorily, though large quantities of lubricant must be used to flush away scale loosened from the steel during forming. Should production quantity warrant, rolls for forming hot rolled unpickled steel should be made from high carbon, high chromium steel to resist abrasive action of the scale. Although this steel costs up to 60% more than materials normally used for rolls, it will last 4 or 5 times as long in service, and results in over-all cost reduction per part.

A variety of precoated materials can be roll formed without damaging the coating. Galvanized steel can be readily formed if proper care is taken in keeping rolls free of zinc pick-up. Metals pre-coated with organic finishes can be roll formed without damage to finish and without any lubricant on the material or rolls. On heavier gages of material (over 0.030 in.) bend radii must be kept large enough to avoid cracking of coating at bends. Since elasticity of different coatings varies, test bends should be made on coated specimens to determine minimum bend radii. Tooling costs for forming this type of material may be slightly higher than normal since highly polished or chromium plated rolls are recommended for forming these materials without a lubricant.

Speed of forming stainless

steels is usually held to 100 fpm in order to preserve a highly polished finish on the product. The heavier the gage of material, the slower the forming speed must be since more roll pressure is required for heavier material.

Aluminum and most of its alloys are well suited to roll forming and in many cases can be formed interchangeably with cold rolled steel on the same set of rolls. Because of the many different types of aluminum alloys available, product manufacturers should consult with aluminum producers for the type best suited to their needs. Other sheet materials such as copper, brass, bronze, zinc, tinplate and copper-plated steel can be roll formed without difficulty. Titanium and zirconium have been cold rolled experimentally, but only enough to indicate the possibility of success when bending properties of the materials can be held uniform.

Shapes and design possibilities

Highly intricate shapes can be produced by roll forming. General design limitations such as minimum bend radii, for each type of sheet metal are similar to those of any other sheet metal forming method. The only cause for variations in dimensions and shape are variations in hardness and gage of material being formed. Tolerances of ±0.002 to ±0.015 in. can be held, depending on size of shape, tolerance on the gage of material and accuracy of the tooling. As-rolled finish on parts is almost always equal to the finish on the part prior to rolling.

Commercially, thickness of sheet material varies from 0.005 to ⅛ in., though properly designed shapes can be formed at low speeds in thicknesses up to ½ or ¾ in. At present, equipment for roll forming is available for forming strip from a fraction of an inch up to 80 in. in width. However, aside from electric-welded tubing, the greatest volume of cold roll-formed products are made from strip less than 0.125 in. thick and under 20 in. in width. With increases in size of metal, investment in equipment becomes progressively greater and demand usually smaller.

A number of production operations can be combined with the roll forming operation to reduce over-all costs of producing a product. Flying shear cutoff machines can chop off parts at desired lengths within tolerances of 1/64 in. Uniformly spaced holes can sometimes be pierced in a roll pass, or irregular shaped holes and notches can be made by synchronizing automatic press operations with roll forming machines. Embossing of designs and printing of trademarks or names can be combined with the forming operation. Coiling of rings and curing can be done on the machines, making such parts as bicycle and headlamp rims. Also it is not uncommon today to combine several press operations with roll forming to produce a finished product.

More tubing and pipe is being produced today by cold roll forming than by any other method. Plain butted tube, lap seam tube, lock seam tube, double wall tube, and all types of welded tube are roll formed. Round, square, oval and odd shaped tubes are produced. Roll formed tubes have been made from ⅛ to 26 in. dia, with walls from 0.010 to ½ in. thick. Tubing has been made from

What is roll forming?

Cold roll forming is a process of forming metal from sheet, strip or coiled stock, into shapes of uniform cross-section by feeding the material at room temperature through successive pairs of rolls. Each pair of rolls progressively forms the sheet or strip until desired cross section is produced. The material is formed at relatively high speeds depending on type of material being formed, shape and gage of material. Variety of shapes possible is wide, ranging from simple channels to complicated types of lock-seam tubing.

Roll Formed Shapes vs Extrusions

There are many shapes that can be produced either by extrusion or cold roll forming. Selection of the forming method is dictated by production quantity, precision necessary, facilities available, end use of the part, and other economic considerations. Roll formed shapes require no straightening and are ready to use as they come from the forming machine. Surface finish is generally less porous than extruded finish and thus less subject to corrosion.

For small quantity production, extrusion tooling is less expensive than roll form tooling; however, it wears more rapidly over progressively longer production runs. Therefore, for long range volume production, roll forming is generally more economical for producing accurate uniform parts.

Another aspect to be considered is the advisability of setting up machinery in your own shop to produce roll formed shapes. Extruding presses are expensive, limiting the number of shops that can economically produce their own extrusions. Machinery for roll forming is less expensive, and many small shops now produce their own roll formed shapes. There are several companies specializing in producing roll formed shapes to customer specifications. The decision by any company as to whether to set up their own forming facilities should be based on production requirements and economic considerations peculiar to each case.

hot and cold rolled steel, stainless steel, aluminum, copper, brass, tin plate and galvanized steel.

Method of welding roll formed tubing depends on materials to be welded, production requirements and maximum size of the tube or pipe to be produced. Resistance welding is being used on many types of mechanical tubing and pipe. On the smaller sizes, cold rolled or hot rolled pickled steel is used since the electrodes must make intimate contact with the tube surface. On larger sizes, tubes are made of hot rolled steel with the outside surface cleaned of scale for several inches from each edge. Unpickled steel can be used for induction welded tubing since no electrical contact is necessary. High frequency induction welding is being used for welding tube made of aluminum, brass, stainless steel, nickel and its alloys and lighter gages of carbon steel. Tubing with walls as thin as 1% of the diameter is being roll formed and welded with this type of equipment.

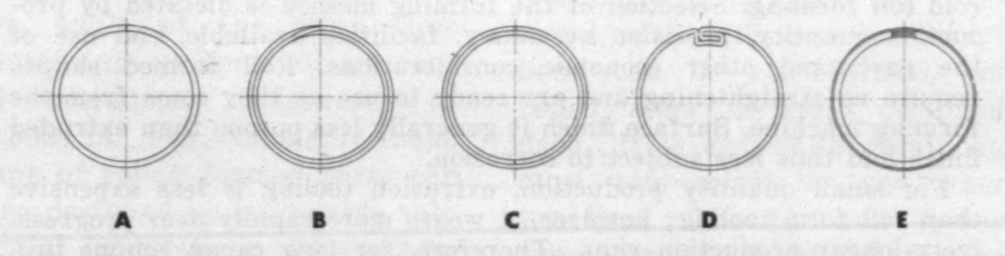
Cost factors

Cost of roll formed shapes depends on the cost of rolls or tooling, cost of material, and labor costs in producing the shape.

Cost of the rolls depends on intricacy of shape, size of shape, type and gage of material formed, and the material from which the rolls are made. Design of shape determines the number of roll passes required. Size of shape determines the size of machine required and size of rolls. Type and gage of material affect finish required on the rolls, roll material and size of rolls and machine.

In order, then, to minimize roll cost, shapes should be as simple as possible, of as light a gage as possible, with over-all dimensions as small as possible, with dimensional tolerances as liberal as possible, and made from material most economical for projected use. Apart from the cost of rolls, which is the major variable, production costs for different shapes do not vary much. A line may be operated with one or two men depending on gage of material. Daily production rates up to 50,000 ft per 8 hr day are not unusual with one-man line operation.

As mentioned before, economical production of roll formed shapes usually starts when quantity requirements reach the 25,000 ft mark. This is due to the cost factors just discussed. However, in many cases where production needs would not seem to indicate roll forming, the savings in production costs, uniform quality of the product which in turn reduces costs, and other factors such as increased strength-to-weight ratios, strongly indicate the use of roll formed shapes.



Wide variety of tubing can be automatically produced by roll forming. **(A)** *Butted seam tube—Generally made of aluminum, it is used in large quantities for TV antennas.* **(B)** *Double wall tube—One piece lap joint construction, it is made of copper-coated steel and furnace brazed after forming. Used in automotive and appliance industry.* **(C)** *Double wall tube—Two piece butted joint construction, it is made of copper-coated steel and furnace brazed after forming. Also used in automotive and appliance industry.* **(D)** *Lock seam tube—Made from all metals, it can be made with thin walls for mechanical tubing.* **(E)** *Double wall lock seam tube—Outer wall of non-corrosive stainless steel or brass, the inner tube is of cold rolled steel. Used where corrosion resistance is a factor.*

Applications

Practically all modern transportation equipment makes use of roll formed parts in their construction. Frames of rail cars, both passenger and freight, are made from roll formed high tensile steel. Stainless steel exteriors of rail passenger cars are roll formed as well as much of the metal work in interiors. These parts can be roll formed to the full 80 ft length of the cars, eliminating vertical joints. Framing, siding and flooring of truck trailers are of roll formed parts, as is the framework of aircraft. High production of uniformly accurate parts needed for automobiles has dictated use of roll formed shapes in that industry. Bicycle rims, fenders and frames are roll formed to minimize costs, as are baby carriage frames and wheel rims.

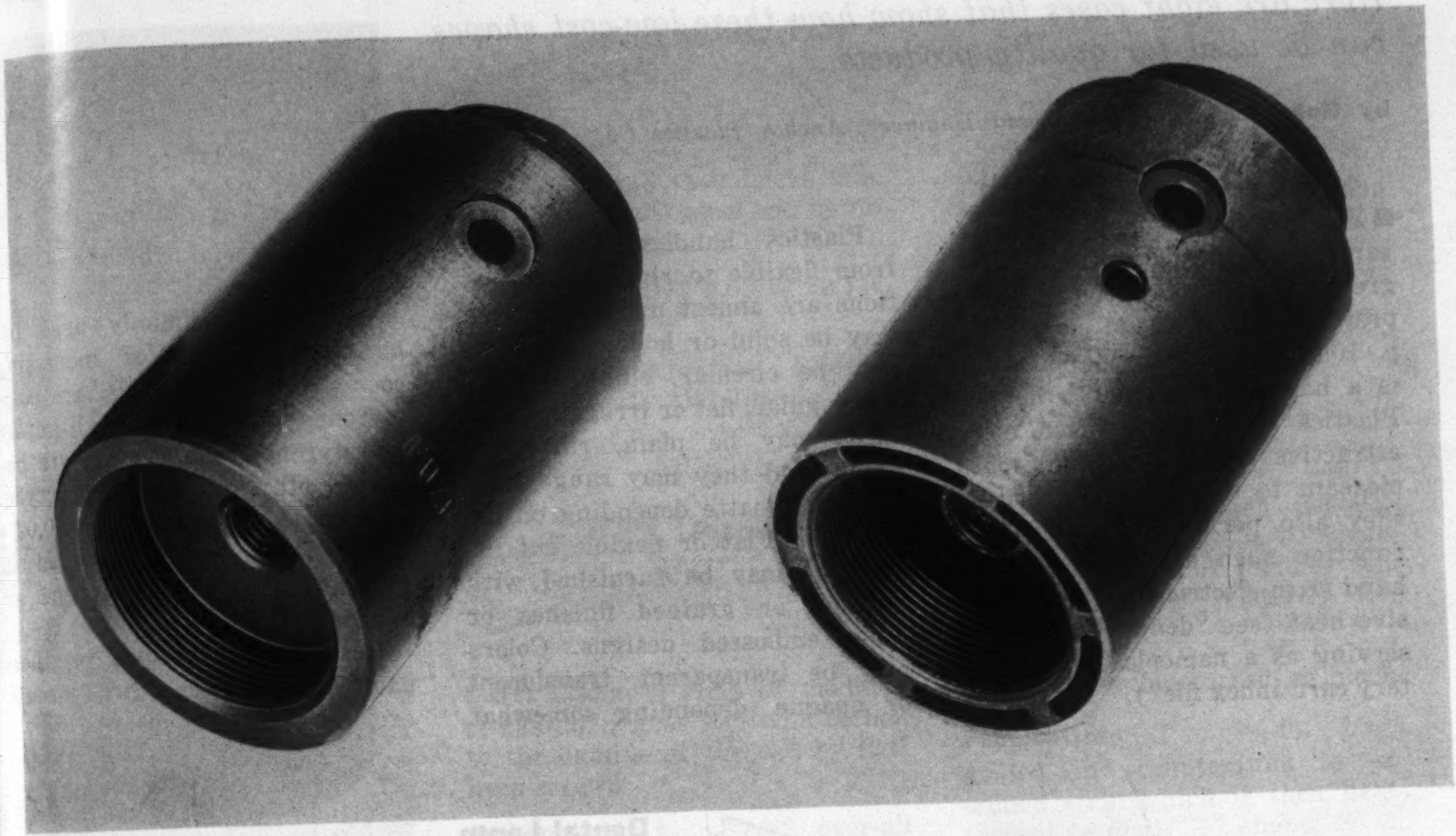
In the home appliance field, outside cabinet and inside shelves of refrigerators, stove and washing machine parts, card tables, folding chairs and many other items used in homes utilize roll formed parts.

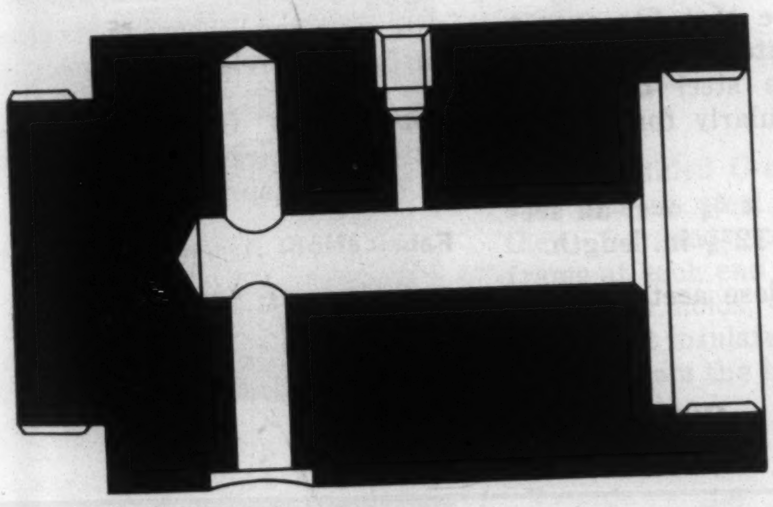
In the building construction field, entire buildings are made of roll formed steel shapes. These shapes are used for farm buildings, warehouses and factories for both permanent and temporary construction. In home building, metal frames, metal siding, roofing gutters, down spouts, awnings, venetian blinds, window and screen frames and many other items are roll formed.

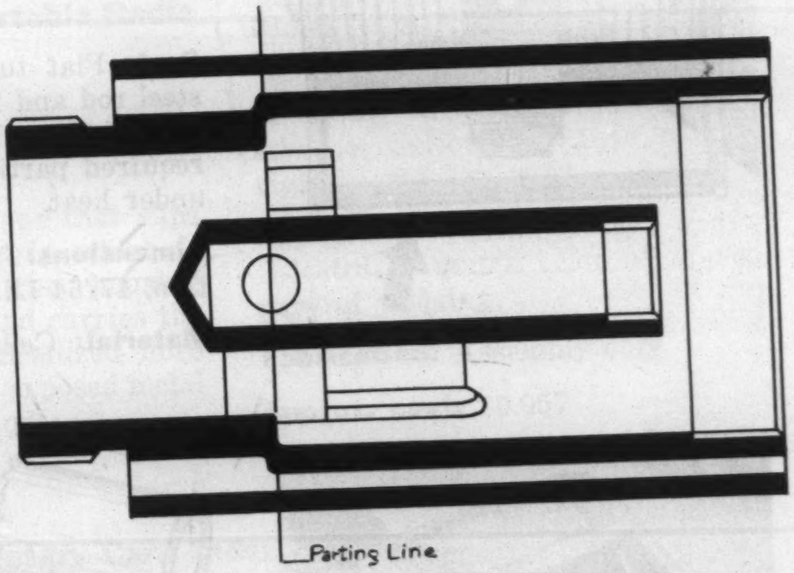
In the window channel of automobiles several materials are roll formed together. The channel is formed from cold rolled steel, a fabric is added for glass to slide in, and two edges are trimmed with a stainless steel bead. All forming and assembly work here is done in one roll forming operation.

Some types of filled welding rod are manufactured in one operation by partially roll forming a tube, filling it with the proper material, closing the tube, and pinching it off at proper length with an automatic flying cut-off machine.

A switch from wrought aluminum to ➡ cast zinc... slashes cost of rocket fuse







An interesting turnabout was effected recently when an aluminum fuse for a rocket was redesigned as a zinc die casting. Weight being at a premium in airborne structures, the change was unusual to say the least. How the change was brought about while maintaining in zinc (specific gravity 2.4 times that of aluminum) the same weight as the aluminum fuse is shown above. Weight was held to 6155 ±115 grains (7000 grains=1 lb).

The change, made by Monarch Governor Co. of Willow Run, resulted in a 50% cost reduction. The original aluminum fuse was turned on a screw machine from bar stock. By producing the fuse as a cored zinc die casting, the following operations were eliminated: 1) cut off, 2) drilling three holes, 3) threading two holes, and 4) anodizing. The zinc die casting requires the following operations subsequent to ejection from the die: 1) trimming flash, 2) cutting two threads, and 3) dichromate dip. Production rate has been increased from 100 aluminum fuses to 150 zinc die castings in the same amount of time.

Plastics Extrusions

Here are eight cases that show how these low-cost shapes can be used for quality products.

by Robert Marx, *Development Engineer, Anchor Plastics Co.*

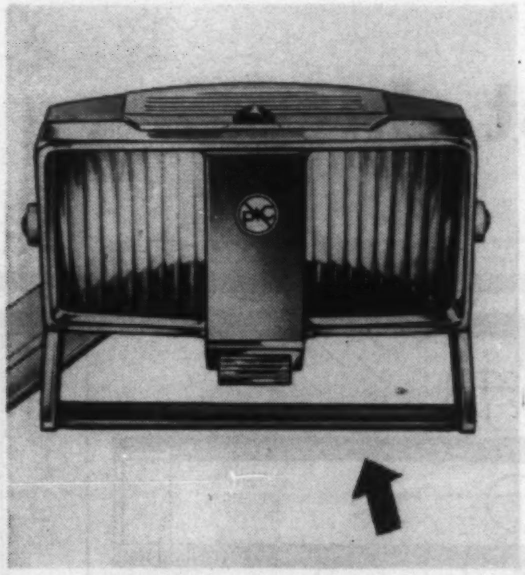
■ Plastics extrusions perform a variety of functions in an even greater variety of products (see previous article, M&M, Jan. 1954, p. 100). One common application is a handle or part of a handle. Plastics handles are often more attractive than metal and more pleasant to the touch. Sometimes they also perform an additional function such as protecting the hand from electric shock or excessive heat (see "dental lamp"), or serving as a nameplate (see "rotary card index file").

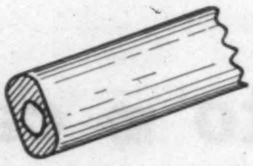
Plastics handles may range from flexible to rigid. Cross sections are almost unlimited. They may be solid or hollow, and they may be circular, elliptical, oval, rectangular, flat or irregular. Surfaces may be plain, ribbed or fluted, and they may range from glossy to matte depending on the material. Flat or flexible cut extrusions may be furnished with knurled or grained finishes or other embossed designs. Colors may be transparent, translucent or opaque, depending somewhat on the material which has been selected.

Materials commonly used for handles, in order of increasing cost on a volume basis, are polystyrene, polyethylene, high-impact polystyrene, cellulose acetate butyrate, ethyl cellulose and acrylic. Thin sections (smaller than 0.025-0.030 in.) must be avoided in designing with polystyrene or acrylic.

Cost of parts shown on these pages ranges from 1 to 14 cents, excluding tooling cost.

Dental Lamp





Part: Flat tube that fits over a steel rod and into recesses in two end pieces, the steel rod being required particularly for rigidity under heat.

Dimensions: ⅜ x ¾ over-all section, 17/64 i.d., 12¾ in. length.

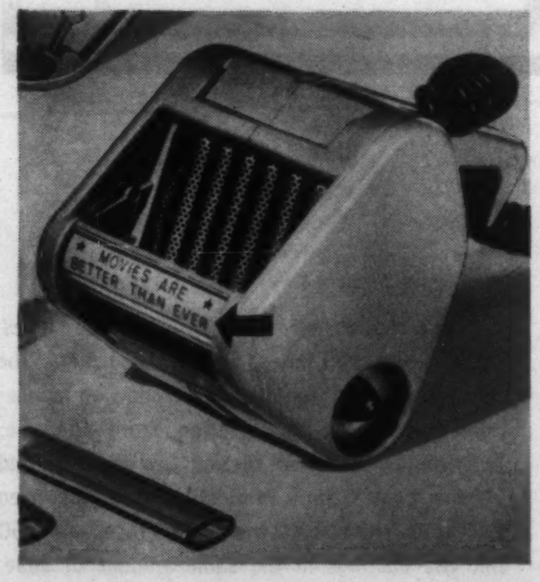
Material: Cellulose acetate butyrate. Selected because of its glossy surface and relatively low cost.

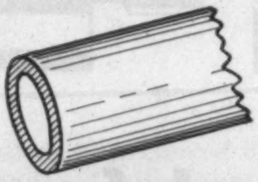
Appearance: Glossy black. Selected to contrast with light color of lamp housing.

Fabrication: Assembly only

Approx. cost: $0.025

Outdoor Movie Speaker





Part: Thick-wall elliptically-shaped tube whose ends fit into recesses in the aluminum speaker housing. A sponge rubber pad at one end prevents rattles and allows free expansion and contraction during weather changes.

Dimensions: 1 x ½ over-all section, ⅛ wall thickness, 4⅛ in. length.

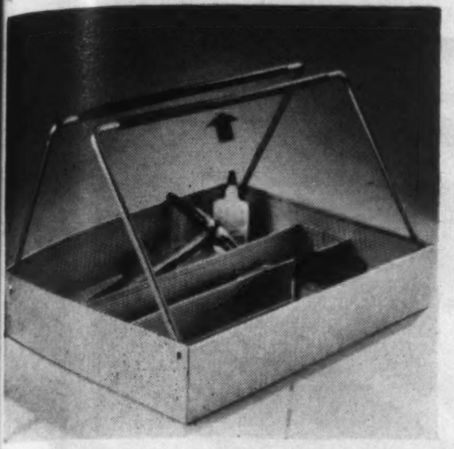
Material: Acrylic. Selected because of its weather resistance, rigidity, scratch resistance and highly glossy finish.

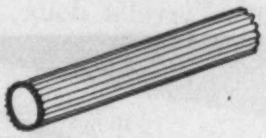
Appearance: Glossy blue tinted. Selected to harmonize with speaker grille color.

Fabrication: Assembly only

Approx. cost: $0.088

Make Good Handles





Utility Tray

Part: Thin-wall cylindrical tube, slipped over each steel rod before it is bent.

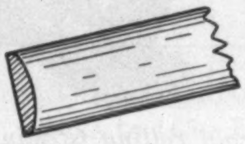
Dimensions: 0.372 o.d., 0.322 i.d., 12 in. length.

Material: Polyethylene. Selected because of its stability in thin sections, its low cost, and its resistance to water, soaps and chemicals.

Appearance: Fluted glossy green.

Fabrication: Assembly only

Approx. cost: $0.01



Picnic Cooler

Part: U-shaped strip of modified rectangular cross section attached to the outside of the can by flat-head screws.

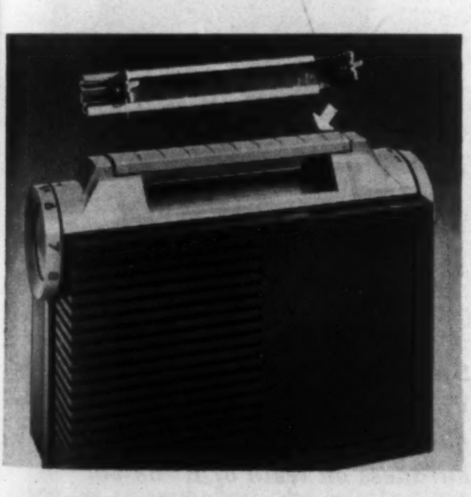
Dimensions: ¾ x 7/32 over-all cross section, 9½ inside width, 6¼ in. over-all height.

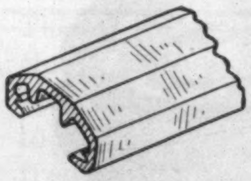
Material: High-impact polystyrene. Selected because of its favorable combination of rigidity and ductility and its relatively low cost.

Appearance: Matte red or black.

Fabrication: Two ⅜-in. holes drilled and countersunk in extruded strip which is then heat-formed to final "U" shape.

Approx. cost: $0.12





Portable Radio

Part: Modified C-shape that slips over a bent steel strip which is then fastened to the housing frame at each end and carries the load; also holds vulcanized fibre insert that insulates exposed metal surface from the hand.

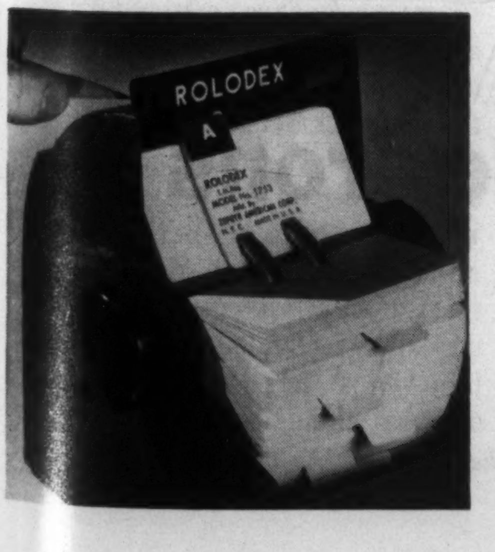
Dimensions: ⅜ over-all height, 1 over-all width, 6¾ in. length.

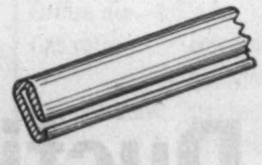
Material: General-purpose polystyrene. Selected because of its rigidity and low cost.

Appearance: Semi-glossy gray. Selected to match color of upper part of housing.

Fabrication: Assembly only

Approx. cost: $0.057





Rotary Card Index File

Part: Thick-wall, slotted flat tube that snaps over a 0.040-in. metal lip and is held in place by its own protruding lip. Serves as combination handle and nameplate.

Dimensions: 9/16 over-all height, ¼ over-all depth, 3-15/32 in. length.

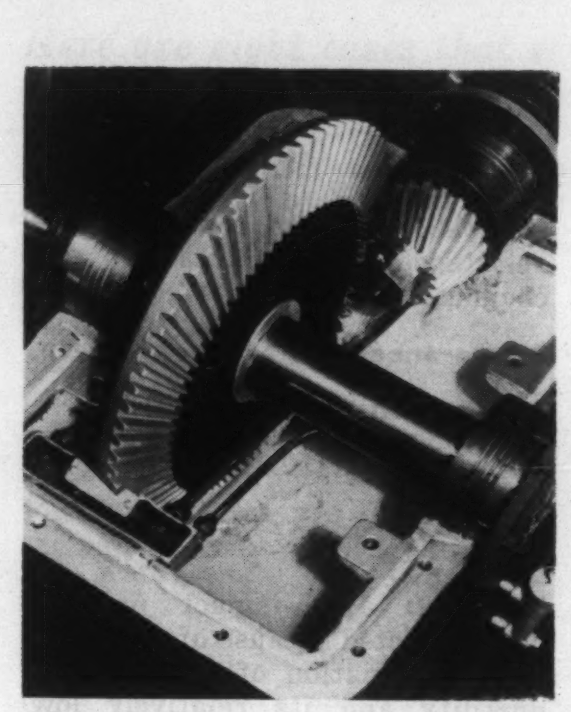
Material: Cellulose acetate butyrate. Selected because of its impact resistance, required to withstand repeated closing of the file.

Appearance: Glossy black.

Fabrication: Letters hot stamped and white paint wiped in.

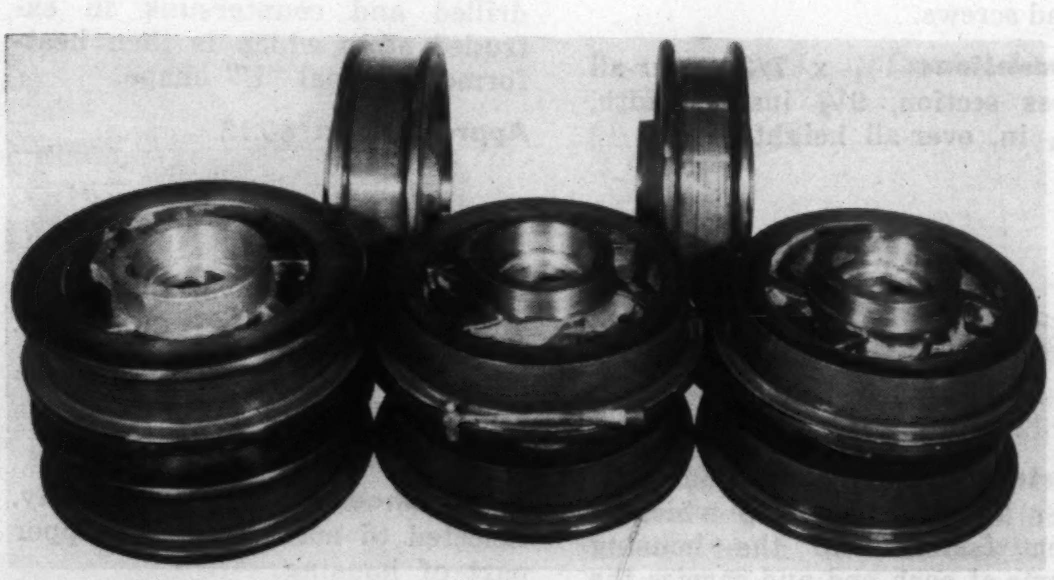
Approx. cost: $0.021

Wear resistance of these parts...

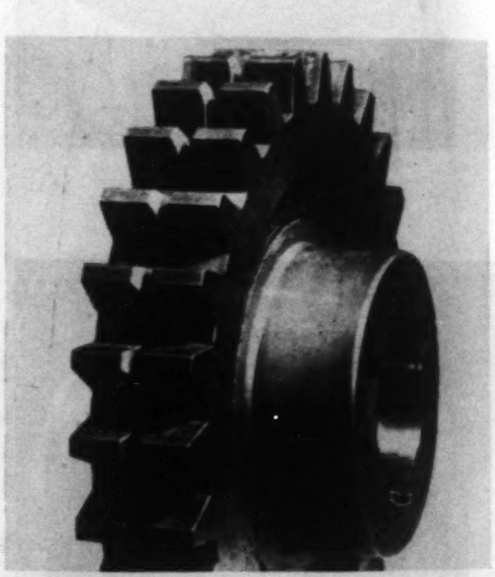


Ring gear *in paper mill drive, formerly made from alloy steel, now made from flame hardened ductile iron.*
(The Black-Clawson Co.)

Iron rolls *for cold rolling titanium. Made of partly pearlitic ductile iron, both roll face and journals were flame hardened to a surface hardness of* R_c *50-55.*
(The Black-Clawson Co. and Detroit Flame Hardening Co.)



Crane wheels, *24 in. in dia, were flame hardened to a surface hardness of Rockwell C55.*
(Detroit Flame Hardening Co.)



Sprocket *for heavy duty silent Hy-Vo chain made of Grade 80-60-03 and flame hardened to obtain a surface hardness on teeth of* R_c *58-60.*
(Morse Chain Co.)

...improved by using

Flame Hardened Ductile Irons

By following the procedures outlined here, surface hardness up to Rockwell C64 can be expected.

by **C. E. Ernst,** *Superintendent,* **R. V. Adair,** *Metallurgist, The Gleason Works, and*
G. L. Cox, *Development & Research Div., The International Nickel Co., Inc.*

Preliminary data and experience in the flame hardening of ductile iron indicate that the material responds well, and has excellent wear resistance, compared with surface hardened cast iron or steel. The technique is similar to that used with alloy steel of medium hardenability.

Flame hardened gears or sprockets have withstood dynamometer and service tests remarkably well. In one test on silent chain, a ductile iron sprocket showed no measurable wear, but merely "polishing" of the contact surface after 8000 hr dynamometer test at 50% overload. The performance characteristics in this case indicated that the flame hardened ductile iron sprocket compared favorably with carburized alloy steel and was better than flame hardened cast steel. A large supplier of ductile iron gears has found that the material in the flame hardened condition outwears cast iron by a considerable margin.

Investigations of Rowady, Murphy and Libsch show that the hardening response to induction heating of ductile iron is dependent upon rate of heating, time and temperature above the critical, and prior structure. A fully pearlitic structure will harden more readily than one that is largely ferritic. A partially pearlitic structure responds adequately to hardening to a satifactory hardness level of about R_c 55. Fully ferritic iron responds less readily and requires either holding for longer times at temperature or increasing the austenitizing temperature. This is to be expected since carbon is more readily introduced into gamma iron from pearlite than from graphite or massive carbides at conventional austenitizing temperatures. As-cast ductile iron, as regularly made in a large number of licensed foundries, is usually a mixture of pearlite and ferrite (e.g., Type 80-60-03), with the graphite present in spheroidal form, and is amenable to the hardening process.

Different metallographic structures can be achieved by alloying as well as by heat treatment. To develop commercial procedures for such alloys, hardening characteristics under commercial techniques commonly used for steels and irons were investigated.

Test blocks cut from several commercial heats of ductile iron were used to establish the hardening characteristics. These included 1) an iron which was substantially all pearlitic in structure [230-270 Brinell hardness number], 2) a partly pearlitic iron [200-230 Brinell] and 3) one mostly ferritic [160-170 Brinell]. Each grade was further modified by annealing, and the harder grades were stress relieved.

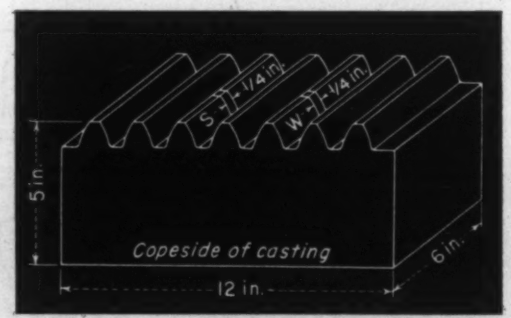
The anneal consisted of heating blocks to 1650 F for 6 hr, a longer than normal time because of the heavy section and to assure removal of all carbides, and holding at 1275 F for 6 hr. Stress relieving consisted of heating the blocks to 1275 F for 6 hr, which resulted in slight lowering of the hardness and some increase in ferrite. This treatment, in effect, is a partial anneal but, of course, would not remove any carbides if present. The stress relieved series was included because it is highly desirable under certain circumstances to remove all casting stresses from gear blanks, dies, etc., prior to hardening.

Procedure

In the practice recommended by Gleason Works for gears, the flame is impinged on the tooth in such a way that the hardened area extends across the top of the tooth, thereby imparting added support at the top to the hardened region. Some experiences indicate this feature produces a better stress pattern to prevent spalling of the case. The maximum hardness usually occurs, however. on the side of the teeth. Operating details are given in a table.

All compositions responded to hardening by water quenching although the low alloy composition in the annealed condition yielded appreciably lower surface hardness, and this hardness extended to only a shallow depth. In the self quench technique, the low alloy type, either as-cast or stress relieved, did not respond to treatment, indicating lack of hardenability in the ferritic matrix.

In general, if the matrix consists entirely, or has a large percentage, of pearlite, the irons respond to both self quench and



Test block for Flame Hardening Tests. S—location of self quenching section for hardness survey. W—location of water quenched section for hardness survey.

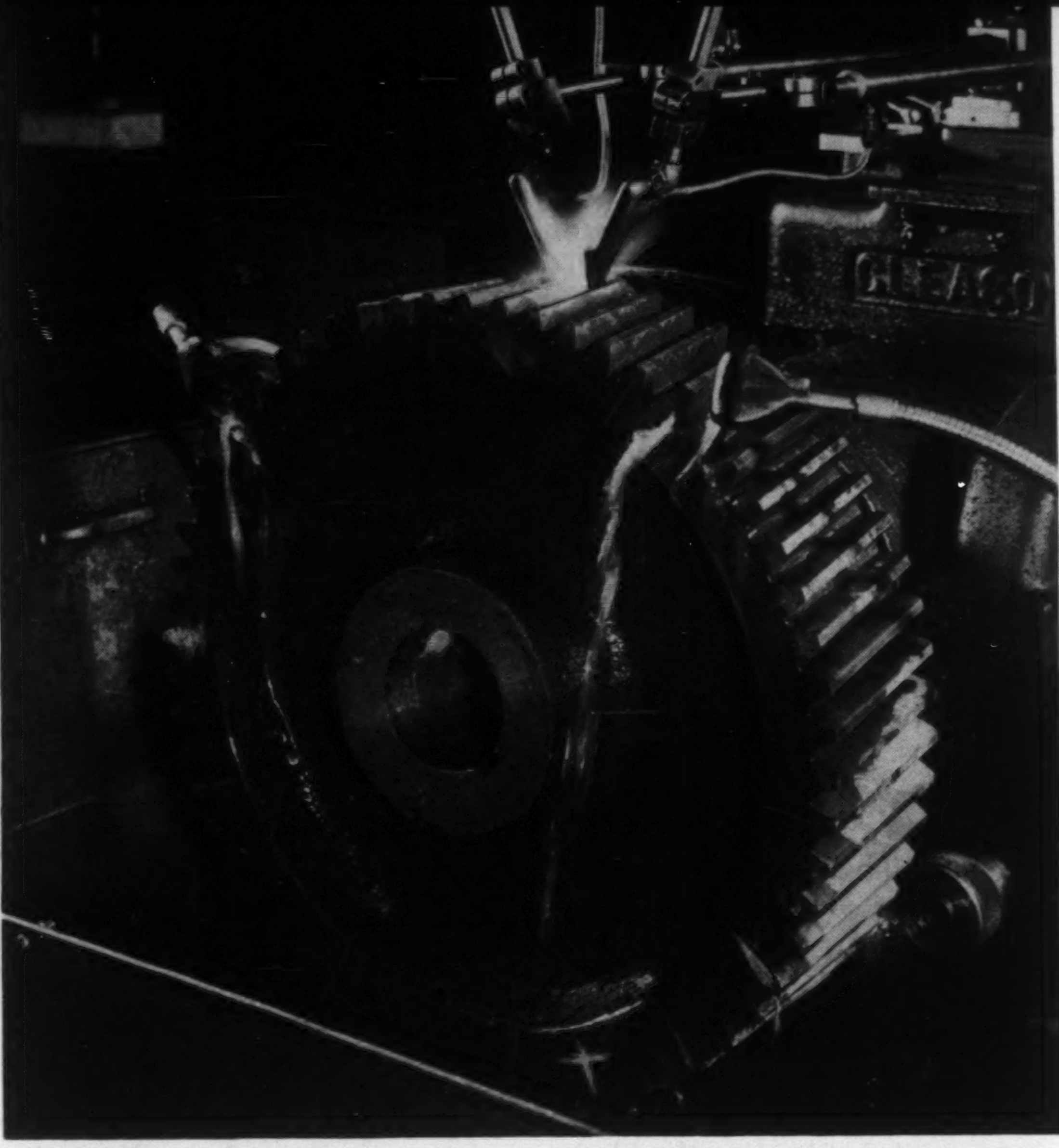
FLAME HARDENING METHODS

Operating Details

Burner orifices, number—6
Orifice dia—0.031 in.
Gas rate: Oxygen —25 to 30 cu ft per min
Acetylene—25 to 30 cu ft per min
Gas pressure: Oxygen —10 to 15 psig
Acetylene—10 to 15 psig
Rate of flame travel—4¾ in./min (will vary slightly due to electronic control)
Distance tip from work—¼ in.
Distance water from flame (in water quenched tests)—¼ to ⅜ in.
Vol of water behind flame—1 to 2 gal/min
Surface temp during heating—1550 ± 25 F (Radiation pyrometer)

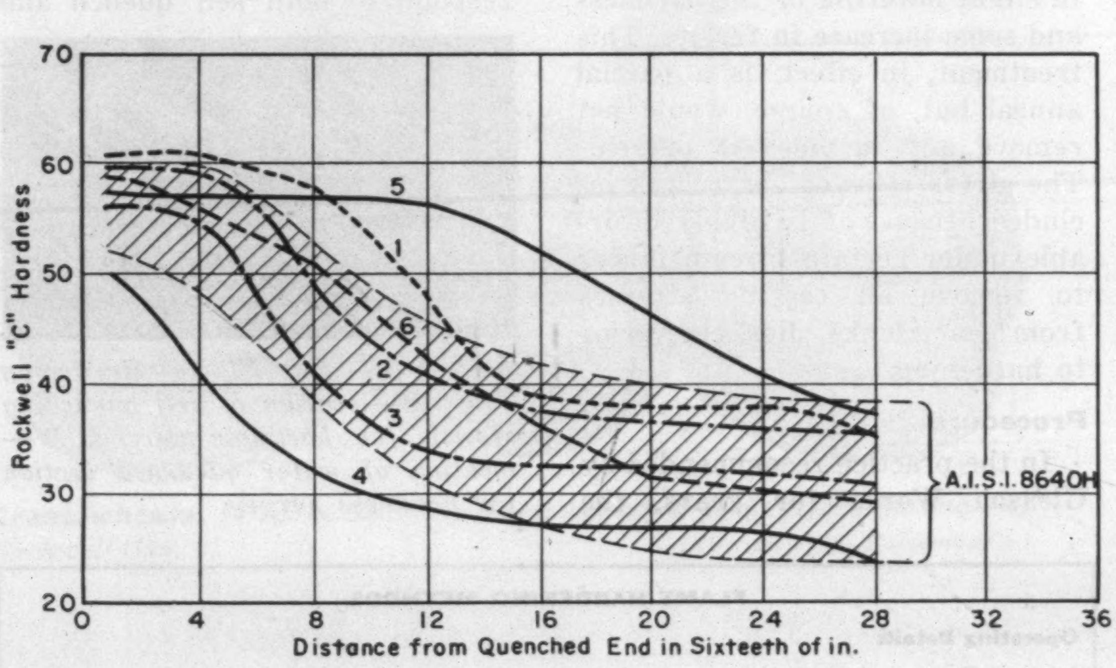
Procedures

1. Water quench behind flame nozzle
2. Self quench, cooling accomplished by mass of material. In this method, coolant is directed on the mass and on teeth ahead of the one being heated.



***Hardening a ductile iron gear** in a Gleason machine.*

(The Black Clawson Co.)



Curve No.	TC	Si	Mn	P	S	Ni	Mg	Quench Temp F
1	3.41	3.01	0.38	0.07	0.020	1.14	0.06/0.09	1700
2	3.26	3.30	0.45	0.09	0.014	1.23	0.06/0.09	1650
3	3.26	3.30	0.45	0.09	0.014	1.23	0.06/0.09	1600
4	3.26	3.30	0.45	0.09	0.014	1.23	0.06/0.09	1550
5	3.38	2.14	0.38	0.02	ND	ND	0.085	1750
6	3.38	2.14	0.38	0.02	ND	ND	0.085	1550

ND—Not Determined, estimated as $S < 0.02$, Ni – 1.25

Jominy curves on ductile iron compared with AISI 8640H steel.

water quench method. If the irons are essentially all ferrite, they do not respond fully under the self quench method. Manganese content of these irons was kept low for high ductility at the particular hardness level, hardenability being achieved by the addition of nickel. Manganese is a strong pearlite former; hence, somewhat greater hardening propensity would be achieved if the manganese level were raised. This practice is sometimes used where it is desirable to increase hardenability of the low nickel iron with, of course, some sacrifice in ductility.

In many applications of surface, or differentially, hardened ductile iron, strength is more important than high elongation. In a gear, if the tooth has bent, the gear has failed as surely as if it broke. Therefore, high strength and yield with some toughness are the essential features.

Recommended commercial practice

Care should be taken that all, or substantially all, of the internal stresses are removed from the castings prior to flame hardening. If the castings are in the as-cast condition and are predominantly pearlitic, they should be given a fairly high temperature stress relief for a relatively short time, as, for example, tempering at 1100-1200 F for 1 hr per in. of casting section. If this is not done in a design where the casting sections are under restraint, cracks may develop under the hardened case.

Following flame hardening, if quenching behind the flame has been used, the castings should be transferred, before cooling to room temperature, to a low temperature stress relief at 300-400 F for an hour or more, and then cooled in air. This serves to reduce the high interface stresses between the hardened zone and the base metal to a harmless level without appreciable reduction in the hardness of the case. It is not necessary to apply this stress relief to material hardened by the self quench method.

In the shop, responsible personnel should know the approximate micro-structure of the iron in order to choose the proper hardening technique. If the pearlite content is high, the self quench method is generally adequate to achieve a satisfactory level of hardness and is the preferred one to minimize stresses developed during hardening. If the pearlite content is low, the water quench method should be chosen, and hardening should be followed by the low temperature stress relief. The authors believe that with proper technique and proper control of temperature of heating (1550-1600 F is common practice), the following ranges of surface hardness of ductile iron in commercial production can be reasonably expected:

1. Ductile iron, fully annealed (ferritic), water quenched behind the flame, R_c 35-45.

2. Ductile iron, partly pearlitic but predominantly ferritic, stress relieved prior to heating, self quenched, R_c 40-45.

3. Ductile iron partly pearlitic but predominantly ferritic, stress relieved prior to heating, water quenched, R_c 50-55.

4. Ductile iron, mostly pearlitic, stress relieved prior to heating, self quenched, R_c 53-58.

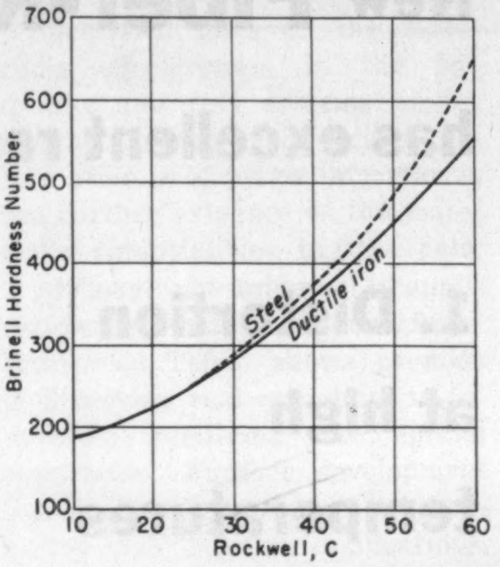
5. Ductile iron, mostly pearlitic, stress relieved before heating, water quenched, R_c 58-62.

Of course, heating temperature and time, influencing the amount of dissolved carbon, section size and rate of quench, are influential factors and determine the final hardness value. Values as high as R_c 64 have been reported where heating time and temperature raises the dissolved carbon level and the quenching was rapid. Burns, Moore and Archer show a maximum hardness of quenched carbon steel of R_c 65 if the carbon content is above 0.55%.

References

E. P. Rowaday, W. J. Murphy and J. F. Libsch, Trans. American Foundrymen's Society, vol. 61, p. 422, 1953.

J. L. Burns, T. L. Moore and R. S. Archer, Trans. American Society for Metals, vol. 26, p. 1, 1938.

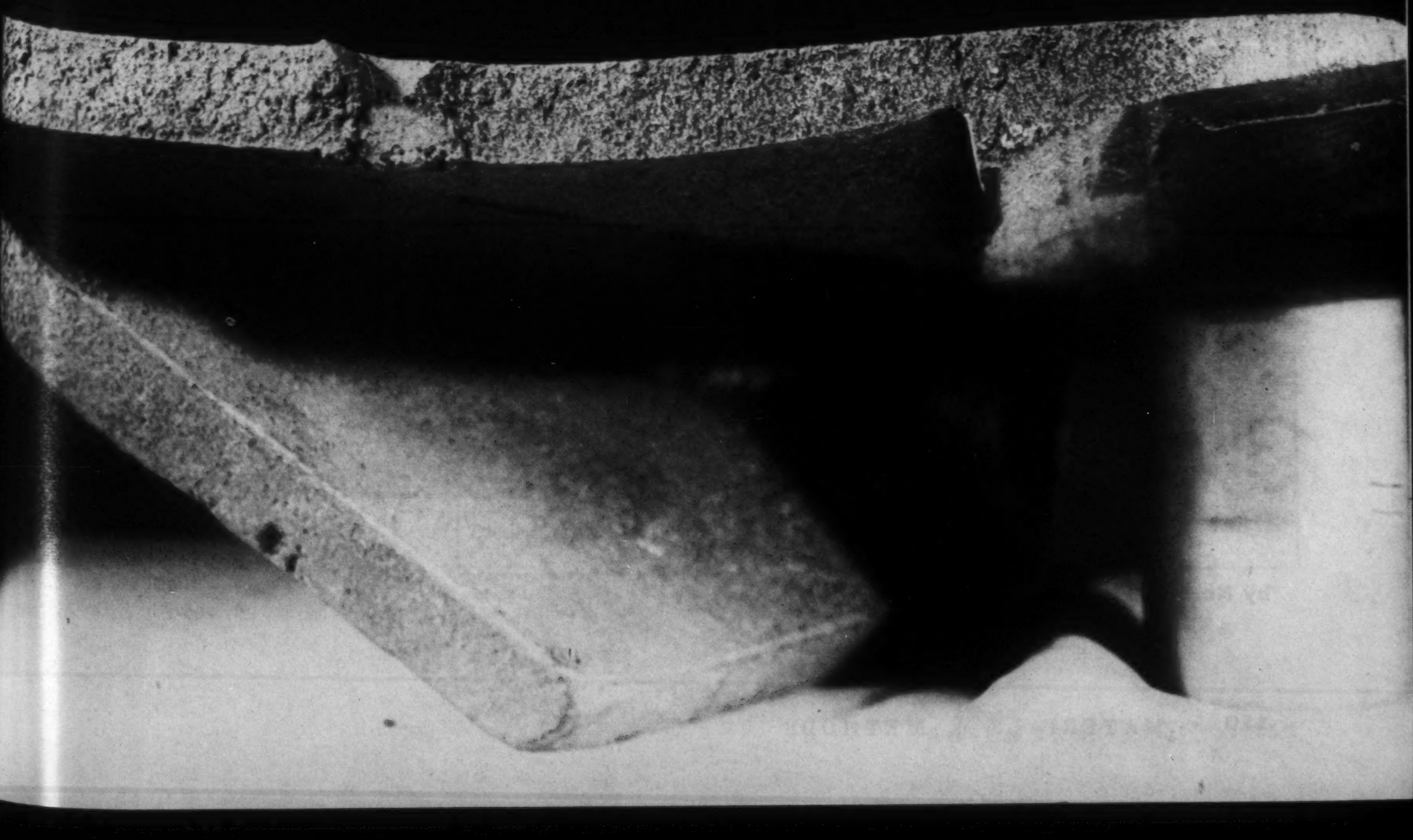


Relationship between Brinell and Rockwell hardness for ductile iron. Conversion from Rockwell-C to Brinell hardness number for steel does not apply exactly to ductile iron in the higher hardness ranges. Conversions for steel are correct up to about R_c 30, beyond which value the diversion from steel increases progressively.

(Cornell University and Gleason Works)

Flame hardened *pearlitic ductile iron plowshare fractured to show hardened cutting edge. Hardness R_c 53-58.*

(Wiard Plow Co. and Jamestown Malleable Iron Corp.)

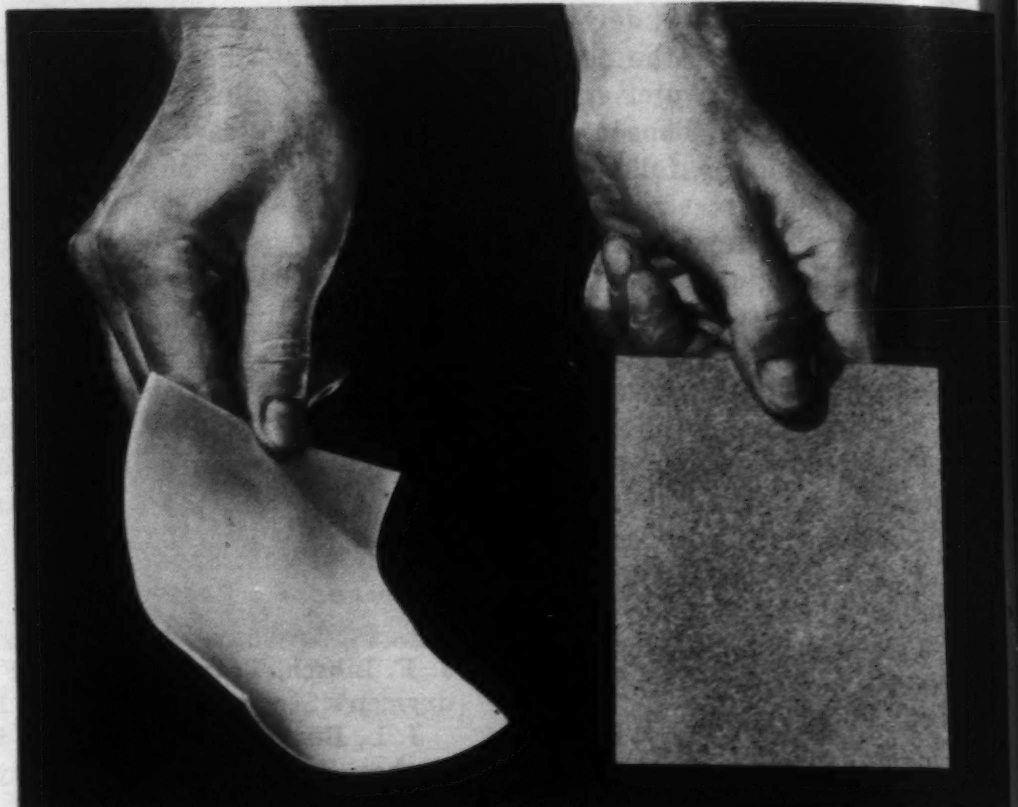


New Fiber-Reinforced Fluorocarbon

has excellent resistance to:

1. Distortion at high temperatures

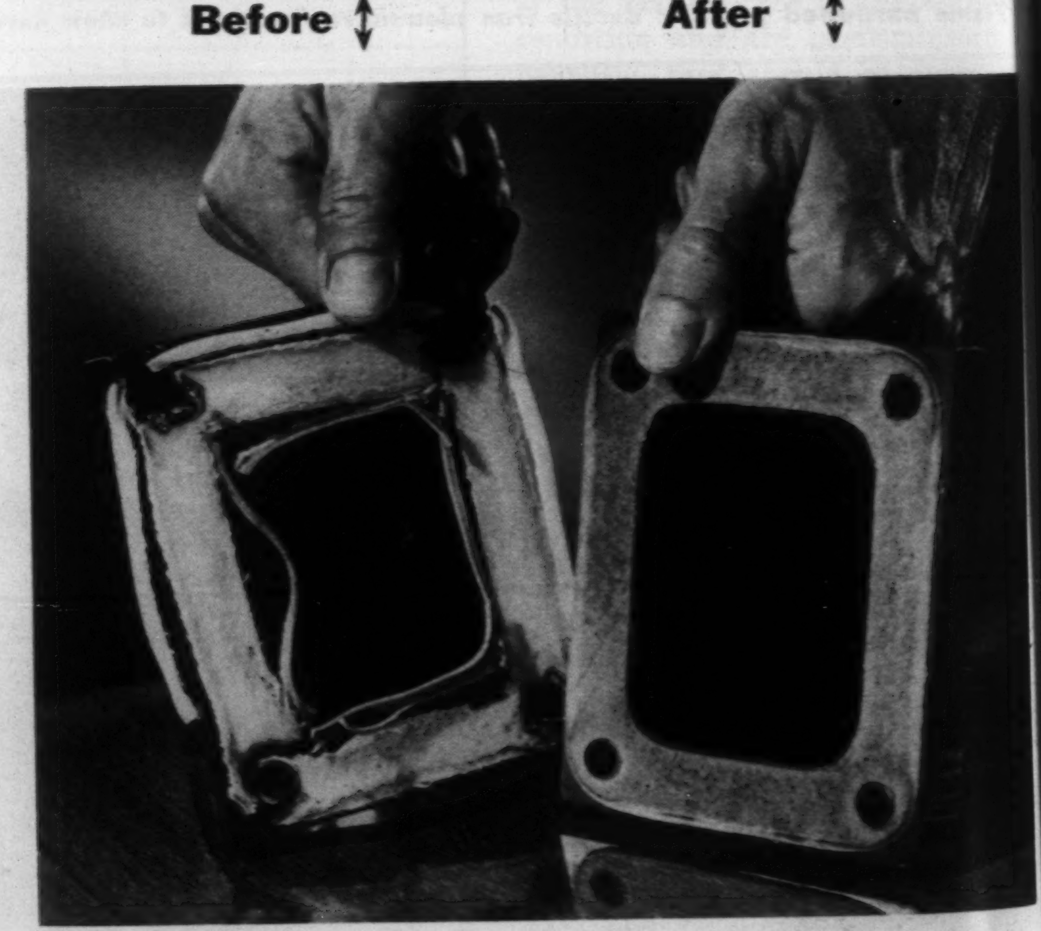
Unreinforced Teflon (left) distorted severely when heated to 720 F and then cooled. New fiber-fluorocarbon retained its original shape.



Before ↕ **After ↕**

2. Cold flow

Unreinforced Teflon (left) extruded and lost all bolt torque when tested at 700 F under torque of 35 lb and 1000 psi flange pressure. New reinforced fluorocarbon retained 15 lb bolt torque, did not extrude.



by **Norman L. Greenman,** *Rogers Corp.*

The high chemical inertness and heat resistance of the fluorocarbon plastic Teflon is now available for those applications in which high resistance to heat distortion, cold flow and extrusion is equally important. This is the promise of successful field tests of a fiber-reinforced Teflon known as Duroid 5600. Released experimentally this year, the material is now available in commercial quantities.

Exceeding most other existing materials in corrosion resistance, the fluorocarbons, since their development in the early post-war years, have been indispensable to the chemical processing industry as gasket materials and for such parts as valve seats and guide bushings. However, their use has been somewhat limited by their tendency to distort at high temperatures and their relatively high cold flow and extrusion.

To produce a material that would overcome these disadvantages, a process was developed to incorporate inert inorganic fibers into pure Teflon and still maintain the structure of the fibers. The resulting reinforced Teflon has met the aims of the program while still retaining its chemical and thermal properties. However, some loss in the quality of Teflon's electrical and dry lubricating characteristics was necessary.

When used for both flat gaskets and machined parts, the reinforced Teflon has demonstrated minimum cold flow while maintaining resistance to corrosive chemicals at high temperatures. Tests consistently indicate that the material can be used in continuous service up to 500 F, and intermittently to 600 F.

Chemical processing firms are currently conducting further tests for such purposes as pump packings, spiral wound gaskets, valve seats and plugs and bearings.

The material will also be of value to many other industries where parts with resistance to deformation and corrosion are required. Duroid 5600 would appear to lend itself to such applications as bearings, gears, filtering media and vibration isolation devices for use in steam or fluids at high temperatures.

Fabrication of reinforced Teflon has also been under testing. All of the parts fabricated have smooth, clean-cut edges although it is recommended that carbide tipped tools be used for long runs on machined parts.

Although initially developed for the chemical processing industry, Duroid 5600 has shown suitability for some aircraft parts where minimum heat distortion and cold flow at elevated temperatures is desirable. One manufacturer, using reinforced Teflon for back-up rings of the flat, scarf-cut type, obtained a run of over 50,000 cycles at 500 F in diester hydraulic fluid without appreciable deterioration.

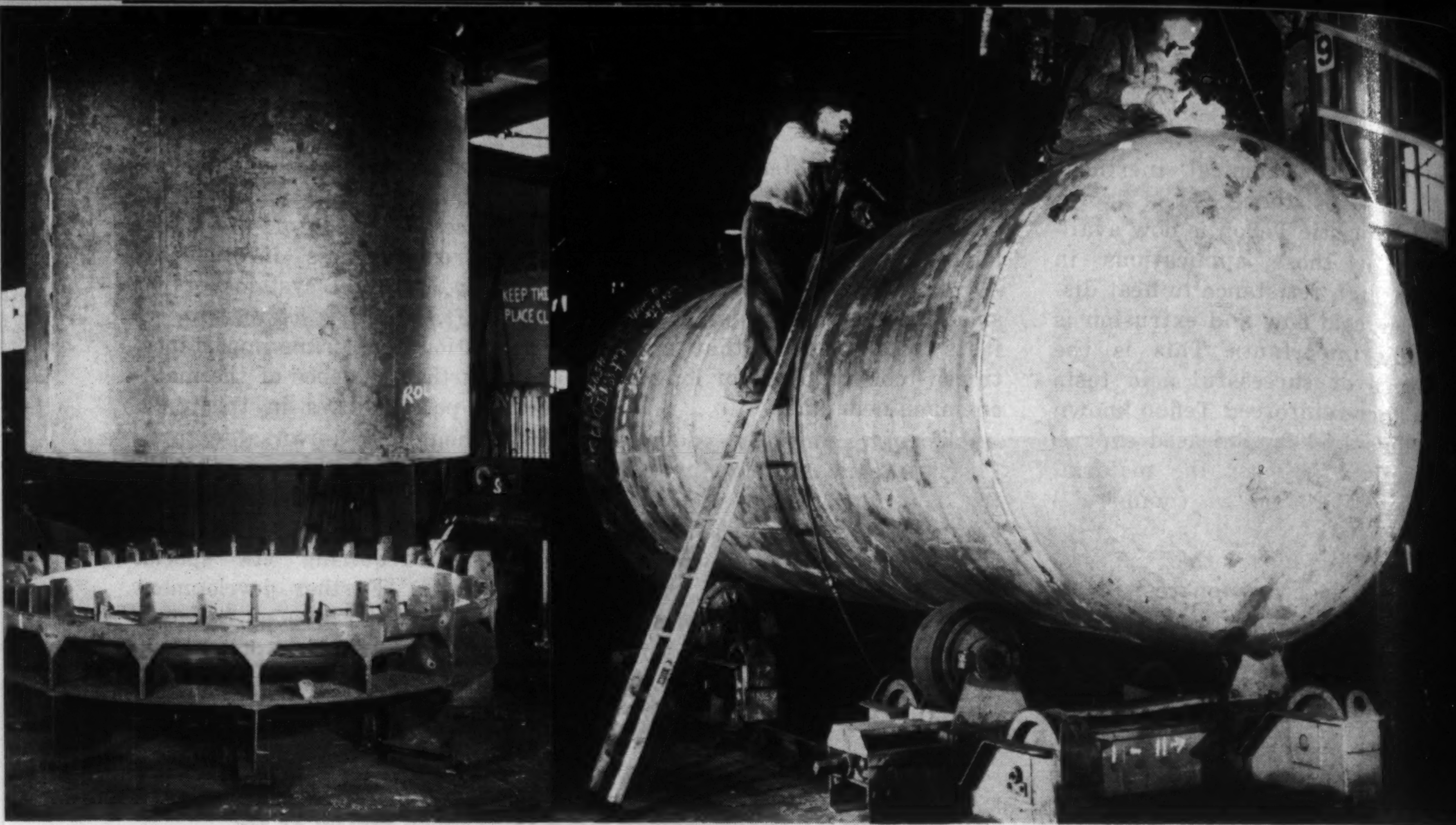
Successful tests of the material's effectiveness in the hydraulic and fuel systems of jet aircraft, where resistance to deformation is of prime importance, are further evidence of the material's potentialities in this field.

Although not universal in application and costly to produce, fiber-reinforced Teflon shows promise of achieving real economies in industries requiring its special properties. Further development will continue to broaden its properties and probable applications, with an increase in the material's electrical properties occupying immediate efforts.

TYPICAL PROPERTIES OF FIBER-REINFORCED TEFLON AT 73F

	ASTM Method	Teflon	D-5600
Ten Str MD, psi	D1170-54T	2800	2500
Ten Str, CMD, psi	D1170-54T	2800	1500
Compressibility, 5000 psi, %	D1170-54T	—	8
Ten Str, MD, psi	D638-52T	1500-3000	—
Ten Str, CMD, psi	D638-52T	1500-3000	—
Stiffness, MD, psi	D747-50	50, -90,000	140,000
Stiffness, CMD, psi	D747-50	50, -90,000	115,000
Impact Str, Izod	D256-47T	—	—
edge, ft-lb/in.		3	1.10
face, ft-lb/in.		3	1.50
Specific Heat, Btu/lb/F		.25	.25
Thermal Expansion Coef/F, 73-140 F	D696-44	5.5×10^{-5}	2.7×10^{-5}
Heat Distortion Temp, F	D648B-45T		
66 psi		250	500
264 psi		—	500
Deformation under Load, %	D621-51		
1200 psi		4-8	2*
2000 psi		25	3*
Dielectric Str, short time, volts/mil	D149-44	400-500	150
Dielectric Constant, 60 cycles	D150-54T	2.00	2.7
10^6 cycles	D150-54T	2.00	2.5
Power Factor, 60 cycles	D150-54T	0.0003	.03
10^6 cycles	D150-54T	0.0003	.003
Surface Resistivity, ohms	D257-52T		
as received		3.6×10^{12}	1.4×10^{13}
96 hr, 100% R.H.		3.6 x 10	4.2×10^{5}
Arc Resistance, sec	D495-48	no track	195
Volume Resistivity, ohm-cm	D257-52T		
as received		$>10^{15}$	4.6×10^{11}
96 hr, 100% R.H.		$>10^{15}$	1.6×10^{7}
Coef of friction against polished steel,			
static		0.04	0.21
kinetic		0.04	0.14
Water Absorption, 24 hr, 70 F		0.005	3.0
Specific Gravity	D792-50	2.1-2.2	1.90

**Made up of actual flow and also of compression under load. Data to indicate breakdown between these two portions is being obtained.*



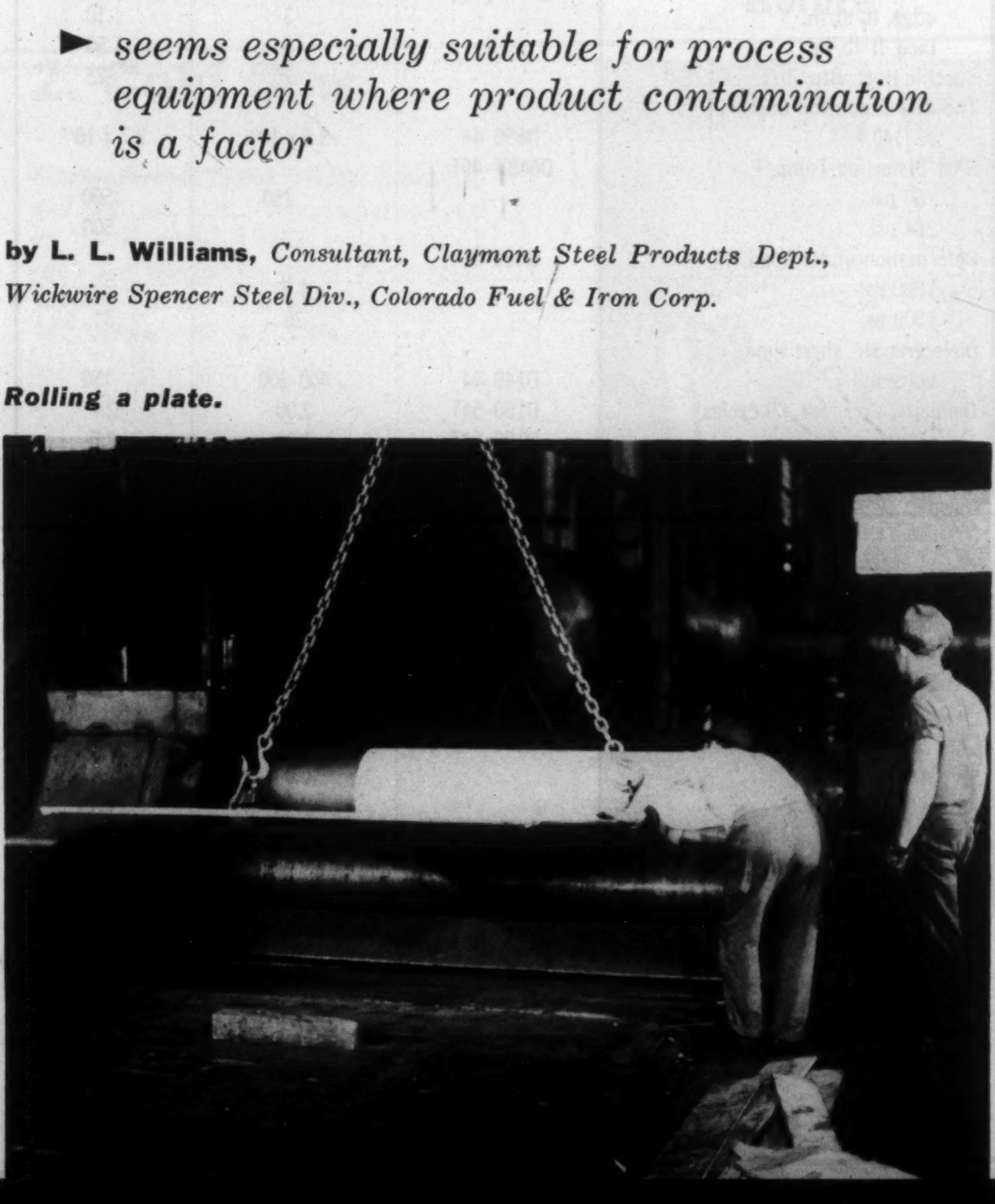
Tanks *made of nickel-plated steel. Plated dished heads are also available.*

Nickel-Plated Steel Sheet and Plate

- ► *costs less than clad steel*
- ► *seems especially suitable for process equipment where product contamination is a factor*

by L. L. Williams, *Consultant, Claymont Steel Products Dept., Wickwire Spencer Steel Div., Colorado Fuel & Iron Corp.*

Rolling a plate.

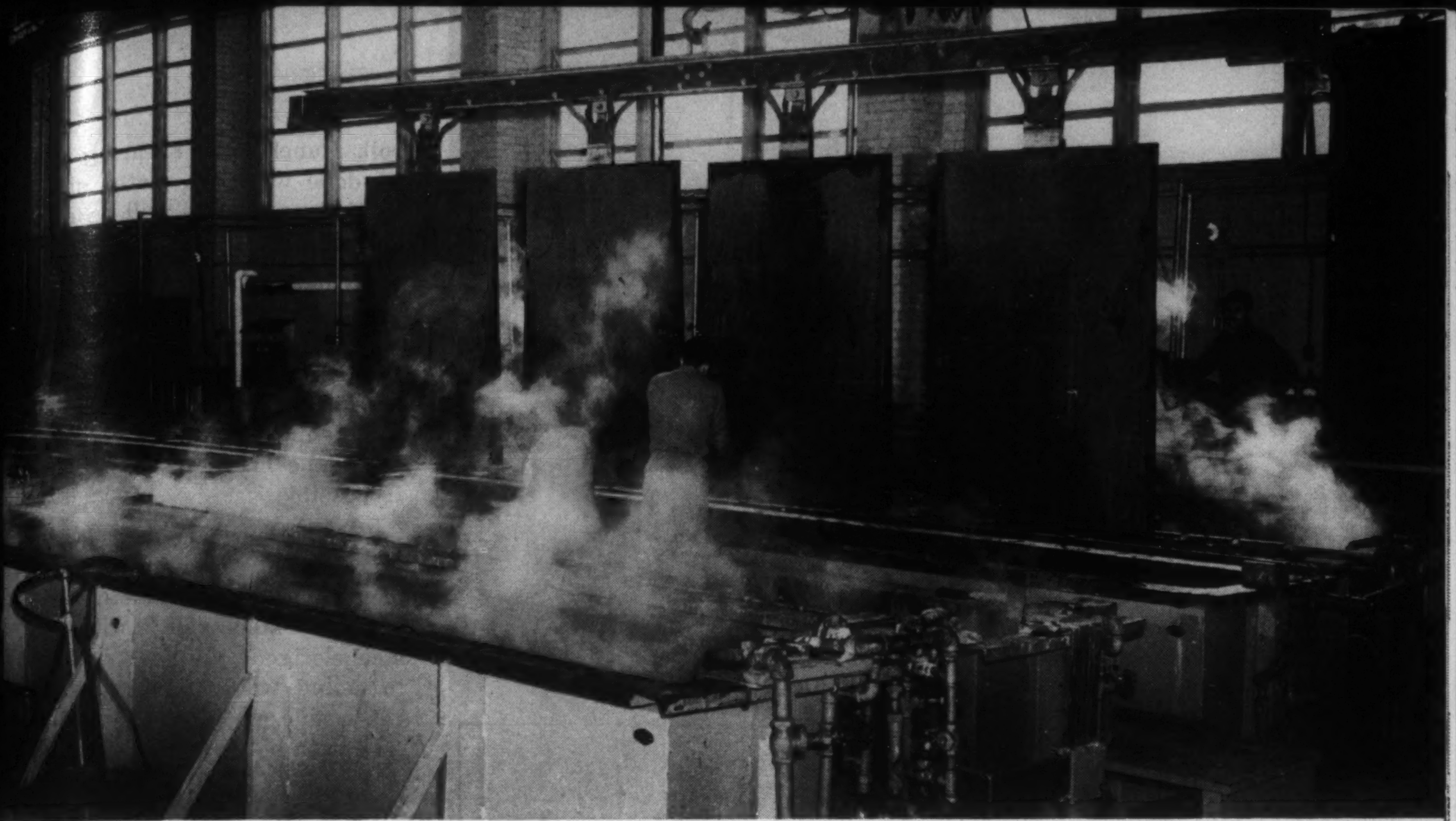


■ A new corrosion-resistant, workable material for process equipment is now available. It consists of steel sheet or plate preplated with nickel on one or both sides.

The nickel plate has good adherence, good ductility and negligible porosity. It is ordinarily 6-8 mils thick on sheet and 8-10 mils thick on plate, but thicker plates of 15 or 20 mils can also be specified. The nickel plate has a smooth, eggshell surface (between matte and semi-gloss) and a color that varies between off-white and light grey.

The base metal may be sheet or plate of any standard carbon or low alloy steel. Sheet is available in U.S.S. gages 7 to 14 (0.184 to 0.077 in.), and plate is available in thicknesses from 3/16 to 1 in. or more. Both sheet and plates are available in widths up to 80 in. and lengths up to 20 ft.

The pre-plated material was developed and is made by Bart Mfg. Corp. The steel plate is made and the plated product marketed by Claymont Steel Products Dept.,



***Careful surface preparation** is the key to a durable, workable nickel plate.*

Wickwire Spencer Steel Div., Colorado Fuel & Iron Corp.

Applications

The outstanding corrosion resistance offered by nickel in many different environments is well known and, in many cases, well supported by detailed data on corrosion rates. Nickel-plated steel is expected to be useful in many applications where nickel, nickel-clad, monel and stainless-clad have previously been successful. Because of the thinness of the nickel layer, however, nickel-plated steel is not recommended for applications where the corrosion rate of nickel exceeds 0.0016 ipy (10 mg per sq dm per day).

Cost of nickel-plated steel (in large quantities) ranges approximately from 52 cents per pound for 14 gage sheet to 14 cents per pound for 1 in. plate. These prices are about 30 to 65% less than those for 10% nickel-clad and 0 to 50% less than those for 10% stainless-clad of comparable thicknesses. Since the thickness of the expensive corrosion-resistant layer remains constant in the plated materials, their cost advantage is greater for thicker materials and less for thinner materials. However, 10% nickel- and stainless-clad are not available in sheet thinner than 7 gage (although thinner gages are available in the form of clad strip).

Hence, for applications where a high degree of corrosion resistance is desired, particularly to avoid product contamination, nickel-plated steel is substantially lower in cost than solid and roll-clad materials. Plated steel has also proved suitable in applications where economic analysis previously resulted in use of unprotected steel or of various organic coatings instead of corrosion-resistant metals.

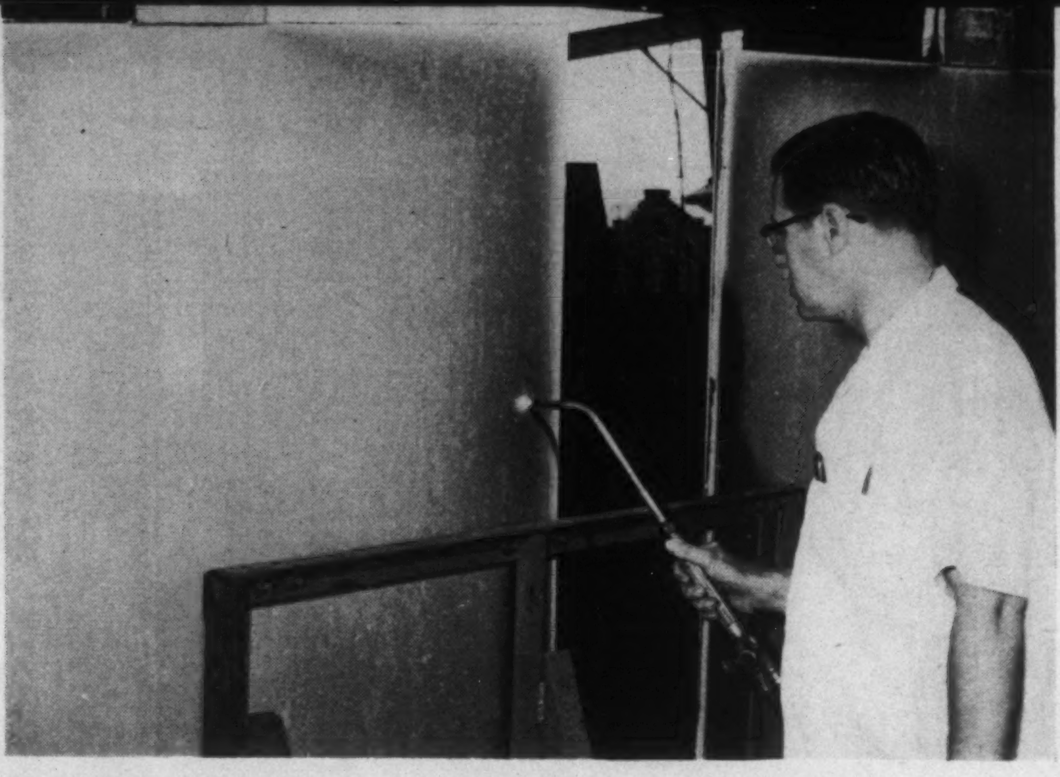
Fabrication

Since the nickel plate is adherent, ductile and strong, the fabrication characteristics of the plated material depend largely on the fabrication characteristics of the base steel, and no special equipment is needed. However, certain techniques—in many cases similar to those used for clad plates—are necessary to protect the nickel plate from damage during fabrication.

Storage and handling—The material is shipped with nickel surfaces facing each other and separated by wood strips, and it should be stored upright in a similar manner. It can also be supplied with a strippable plastic coating. Brass plates should be used to prevent contact between the plated surface and the clamps used in handling the material.

Flame cutting—Preheating is not required, and this material can be flame cut and bevelled for welding at speeds normally used for carbon steel plates of equivalent thickness. It should be flame cut preferably from the steel side. Although the nickel plate will show a blue-black discoloration it will not check or flake. It is not necessary to chip out the nickel plate and flame cut along the chipped line. Slag adhering to the nickel edge after cutting can be removed by hand or by grinding.

Forming—In all forming operations, the working surface of the equipment must be smooth, and both the equipment and the nickel-plated surface must be free of chips and other foreign matter. In addition, a piece of heavy kraft paper should be inserted between the plated surface and the die or



Flame test *checks adherence of nickel plate.*

roll. Punching or shearing should be done with the plated side up so that any burrs will be on the steel side.

Layout—If the material is furnished with a strippable plastic coating it should be retained during layout. Soapstone is the only marking material recommended for the nickel surface. Tack welds should be made on the steel side if possible.

Welding—Either manual arc or inert-gas arc welding is recommended. Normal practice is to weld the steel side with a mild steel electrode, chip or grind down to sound weld metal on the reverse side, then weld the plated side with a nickel electrode. The nickel plate is protected against oxidation by maintaining a low heat input and by coating the nickel surface with an anti-splatter or lime wash. The joint should be designed so that a minimum of back chipping or grinding and a minimum of nickel weld metal are required. For applications where corrosion or contamination is critical, it is best to use more than one pass on the nickel side to minimize iron dilution of the exposed weld metal. "Inco" rod No. 141, with a current of about 100 amp (for ⅛ in. rod), is recommended for manual arc welding. "Inco" wire No. 61, with current of about 200 amp, voltage of about 24 v and welding speed of about 20 ipm (for 0.045 in. wire), is recommended for inert-gas arc welding (using argon gas for shielding).

Cleaning and finishing—Shop dirt, greases and oils can be removed by a standard alkaline cleaner. Most stains can be removed by a phosphoric acid cleaner. Residual stains can be removed by swabbing the surface with a solution of sulfuric and chromic acids; this mixture must be fully rinsed off with cold water before drying. This material can also be cleaned by sand blasting of limited duration or wire brushing (with a stainless or nickel brush). A satin finish can be produced by light wire brushing.

Process and Specifications

The nickel-plated steel described in this article is produced by Bart's "Lectro-Clad" process, used for more than ten years to nickel plate steel pipe and fittings for nuclear and chemical process equipment.

All steps in the process are carefully controlled. The steel sheet or plate is visually inspected to insure absence of surface defects, electrocleaned in a hot alkaline bath to remove oil, grease and shop dirt, and cathodically pickled to remove mill scale. Any small surface defects that show up in the macro-etched surface are ground out. The steel is then subjected to a controlled anodic etch in sulfuric acid. The nickel plating bath is a modified-Watts type having a high metal concentration, and it is continually purified to remove foreign metal and other contaminates. Finally, each finished sheet or plate is checked for ductility, adherence and porosity.

Following is a summary of the specifications for the nickel plate:

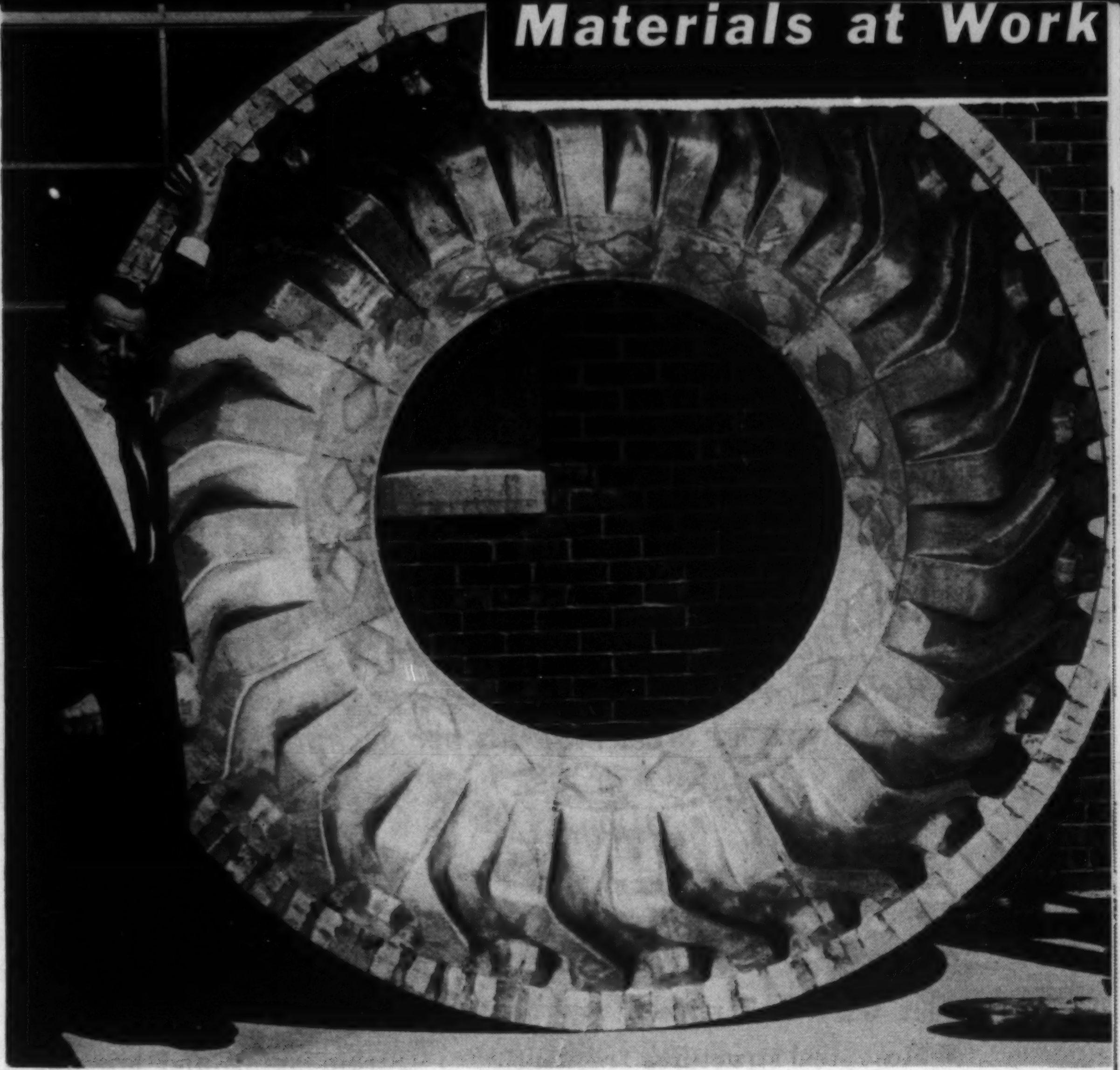
Composition—99.00-99.95 nickel, 0.01 max iron, 0.02 max copper, 0.010 max manganese, 0.005 max lead, and 0.10% max cobalt.

Tensile properties—Equal or superior to the minimum specified properties for base metal.

Ductility—No flaking, checking or spalling in a bend test with the plate in either tension or compression. Bend test may be conducted by bending a small test bar (attached to the sheet or plate during plating) about 180 deg, or by bending the sheet or plate itself at least 90 deg over a ¼-in. rod.

Adherence — Bond strength normally equal to the yield strength of the base metal. No blisters after heating test. Test conducted by heating a series of ½-in. dia areas to 1000-1100 F (cherry red color) with an acetylene torch.

Porosity—No brownish stains on significant surfaces following hot water immersion test, or (where immersion is not feasible) no copper-colored spots on nickel surfaces following copper sulfate test. Hot water immersion test conducted by submerging cleaned plate or sheet in aerated water at 185 ±15 F, removing it from the bath after 30 min, and observing results after another 15-30 min. Copper sulfate test conducted by cleaning the surface with 10% hydrochloric acid, water rinsing, then applying a mixture of 10% copper sulfate and 10% hydrochloric acid solutions which causes copper to plate out wherever the solution is in contact with iron.



Largest cast aluminum tire mold?

Cast in aluminum and weighing 1800 lb, this cast tread ring is being used by Goodyear Tire and Rubber Co. to make 37.5 by 33 tires for road building equipment. Said to be the world's largest cast tire mold, it was cast by Morris Bean and Co. in their Yellow Springs foundry.

Pattern plastic gimmick

By dipping a putty knife in fillet cement solvent before using it to apply pattern plastic, Empire Steel Castings, Inc. has found they are able to govern the amount of plastic used so that only enough excess is left to require a light sanding to finish the job. Pattern plastic is used to fill screw holes, or repair damaged sections of a pattern. Overall results are said to be smoother surfaces, reduced shrinkage and shorter drying time.

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How to Avoid Brittle Failures in Steel

Plain and low-alloy steel structures are susceptible to brittle failure in the temperature range of —20 to 650 F. Fortunately, such failures can be avoided not only by proper steel making practice, but also by 1) careful design, 2) proper heat treatment and 3) care in fabrication.

by G. H. Enzian,

Assistant Director, Technical Services, Jones & Laughlin Steel Corp.

■ Most steel structures frequently encounter temperatures in the range of −20 to 650 F, either during fabrication or in actual service. Unfortunately, plain carbon and low alloy steels are susceptible to brittleness in this temperature range. To avoid failures, it is important to understand the nature of this brittleness and ways to avoid it.

There are two types or forms of brittle behavior that can occur in plain carbon and low alloy steels: 1) notch brittleness and 2) low ductility resulting from strain aging. There seems to be no relation between the two although circumstantial evidence indicates that some of the factors which minimize strain aging also reduce notch brittleness.

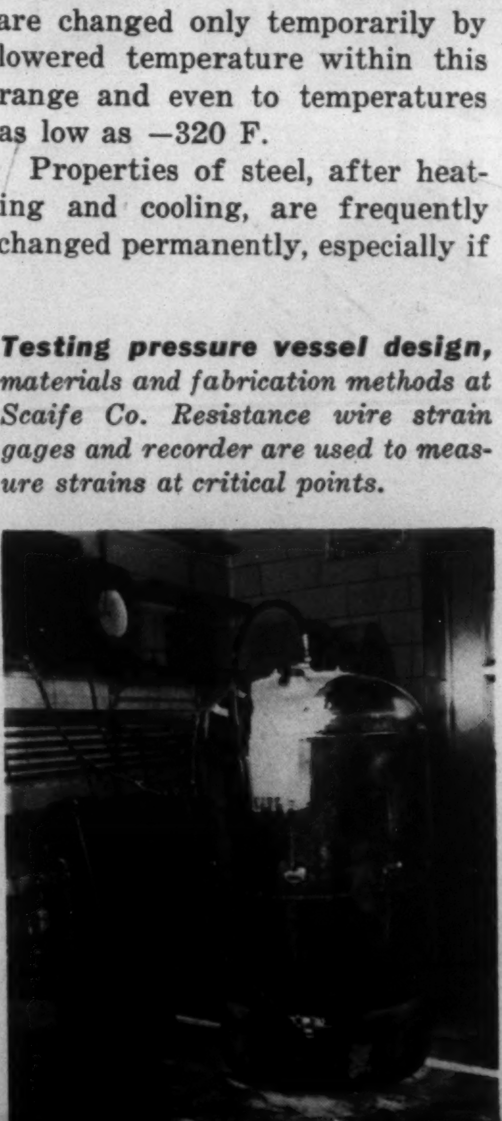
Notch brittleness involves a transition from ductile to brittle behavior. It occurs within narrow temperature limits, usually at room or lower temperatures. It is generally considered to be an inherent characteristic of ferritic iron, but the metallurgical variables influencing changes in the mechanical properties at low temperatures have not been satisfactorily analyzed.

Strain aging and low ductility caused by it are often referred to as blue-heat phenomenon or blue-brittleness. It is attributed to precipitation and generally occurs only at room and higher temperatures.

Notch brittleness and loss of ductility through strain aging may be either temporary or permanent. Generally speaking, the properties of low carbon steels are changed only temporarily by lowered temperature within this range and even to temperatures as low as −320 F.

Properties of steel, after heating and cooling, are frequently changed permanently, especially if the steel has been strained or cold worked, as in bending, punching or shearing before heating. These changes are usually ascribed to strain aging which is greatly accelerated by only slightly elevated temperatures. Another important consideration is the fact that the properties of carbon and low alloy pressure vessel steels within the −20 to 650 F range may vary owing to previous heat treatment at temperatures above this range.

Testing pressure vessel design, *materials and fabrication methods at Scaife Co. Resistance wire strain gages and recorder are used to measure strains at critical points.*



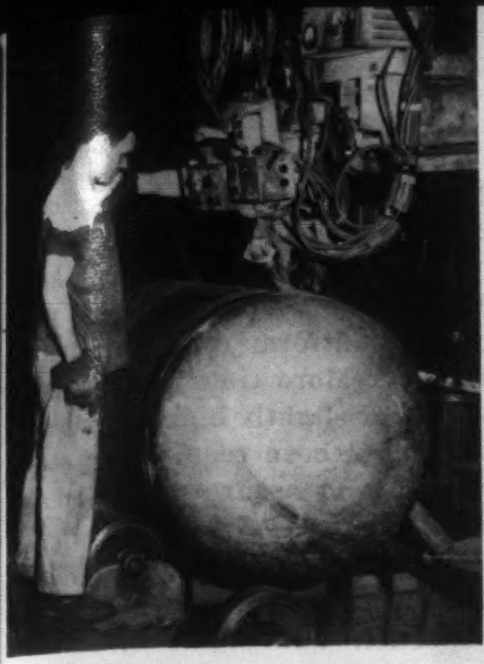
It is generally impossible to use the properties determined at any one temperature to predict their probable value at another temperature without taking into account the method of manufacture, chemical composition, heat treatment, microstructure and other factors, together with experience with the behavior of similar material at various temperatures. Even then there are frequent unexplainable exceptions.

Changes in tensile properties

The general level of yield strength of plain carbon and low alloy steels between −20 and 650 F is influenced to some extent by chemical composition and steel making practice, but these factors apparently have little effect on the rate at which yield strength changes with temperature.

Data on tensile strength show that temperature effects on these steels vary widely. Within the limits specified, tensile strength is influenced by chemical composition, but the variations are most markedly affected by deoxidation practice and sometimes heat treatment. The characteristic increase at blue heat temperature can be directly attributed to nitrogen content and can be controlled, within limits, by deoxidation with such strong nitride-forming elements as aluminum, titanium and vanadium.

Deformations at blue heat and at room temperature are fundamentally different, the difference being attributed principally to precipitation hardening at elevated temperatures. Usually hard-



Automatically controlled welding *of a girth seam contributes to uniformity in quality of welded joints.*

ness and strength begin to increase at temperatures only slightly above ambient, but in some steels, notably the so-called *non-aging* or *stabilized* steels, these properties may decrease continuously up to 300 or 400 F before increasing. In such steels, the increase may or may not be enough to exceed the room temperature value.

Static ductility, as measured by tensile elongation and reduction of area, varies with temperature in the opposite manner to strength and hardness, i.e., ductility is low at temperatures where peak strength is observed. Reduced static ductility may not be accompanied by a loss of impact toughness. Neither does high ductility in tensile tests at low temperatures necessarily indicate adequate notched bar toughness. The change in tensile ductility between room temperature and —20 F is negligible.

Changes in impact properties

Changes in impact properties in this temperature range are in some respects more important than changes in tensile properties and hardness. Embrittlement at a transition temperature within a narrow temperature range is a property of these steels. It is characterized by a change from high notch impact values to low notch impact values, accompanied by a change from fibrous to granular fracture.

Steel making methods have a marked effect on the transition temperature. The importance of deoxidation practice, heat treatment, and grain size has been demonstrated. Although the mechanism resulting from deoxidation is controversial, there is much evidence that best properties are obtained in material treated with aluminum and produced with a fine grain size. Resistance to aging accompanies good low temperature behavior.

Unfortunately, the limited production capacity and higher cost of aluminum killed steel makes it impractical for some structural steel and pressure vessel applications. Therefore, it is important to know what factors affect the brittle behavior of steels that are not aluminum killed.

An increase in the manganese-to-carbon ratio improves impact behavior significantly. There is reason to believe that much of the improvement can be ascribed to the lower carbon content required to obtain the desired tensile strength. Stated in another way, additional manganese is beneficial not only in decreasing the transition temperature, but, for the same strength level, permitting a decrease in carbon content.

There are some indications that the as-rolled impact properties of some steels are influenced somewhat by rolling mill finishing temperatures. Lower finishing temperatures appear to favor slightly lower transition temperatures.

In considering the use of mild steels at low temperatures, two authorities concluded that "if precautions are taken to eliminate notches and the effects of cold work, fully killed mild steel of low-carbon content (under 0.15%) can safely be used at temperatures appreciably below 32 F." The 1954 SAE Handbook reduces the lower limit further: "For most applications (to —25 F), it is probable that plain carbon steel will be satisfactory. In the lower part of this range where the service requires high rates of strain, the selection of fully killed steels in place of rimmed or semi-killed steels is justified."

Transition temperatures vary among plain carbon steels from about —40 to 80 F, and nearly all are very brittle at —100 F. Many of the low alloy steels, on the other hand, have lower transition temperatures. They should be selected for subnormal temperature applications.

Room temperature impact properties of plain carbon steels, after straining in the blue heat range or after heating cold worked material in the range, may be as low as those normally expected at subnormal temperatures. The properties depend somewhat on the amount of cold working and strain sensitivity of the steel.

The minimum impact toughness found in the blue heat range occurs at a considerably higher temperature than that at which a maximum loss of ductility is noted in a static tensile test. This behavior results from the relationship between the rate of age hardening and rate of deformation. For comparatively slow deformation, as in tensile testing, the rate of aging equals the rate of deformation in the blue heat range. In dynamic testing, the rate of deformation is apparently so high that the full effects of aging are not obtained until somewhat higher temperatures are

Check List to Reduce Brittleness

Notch-transition temperature may be lowered by:

1. Increasing degree of deoxidation.
2. Normalizing, or quenching and tempering.
3. Decreasing grain size.
4. Increasing ratio of manganese to carbon contents.
5. Alloying with certain elements, e. g., nickel.
6. Removing the effects of cold work or strain aging, if present.

Strain-aging susceptibility may be reduced by:

1. Increasing degree of deoxidation, especially with strong nitride forming elements.
2. Normalizing.
3. Alloying (comparatively little known).

reached. Cold work has been observed to alter the effect of temperature on impact toughness.

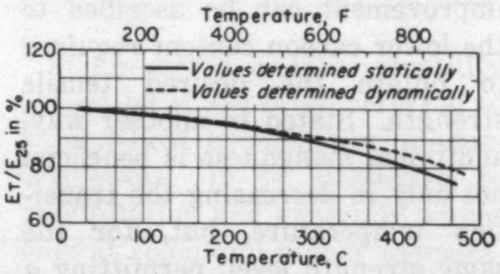
Fatigue properties of steel have not been investigated thoroughly because of difficulty in carrying out tests. However, it has been shown that endurance properties of polished specimens at low temperatures follow the increased tensile strength at these temperatures. An apparent lack of concern about fatigue properties of carbon and low alloy steels at temperatures up to 650 F can probably be construed to indicate that they are of minor importance in the selection of steels for use within the range of —20 to 650 F.

Brittleness and design

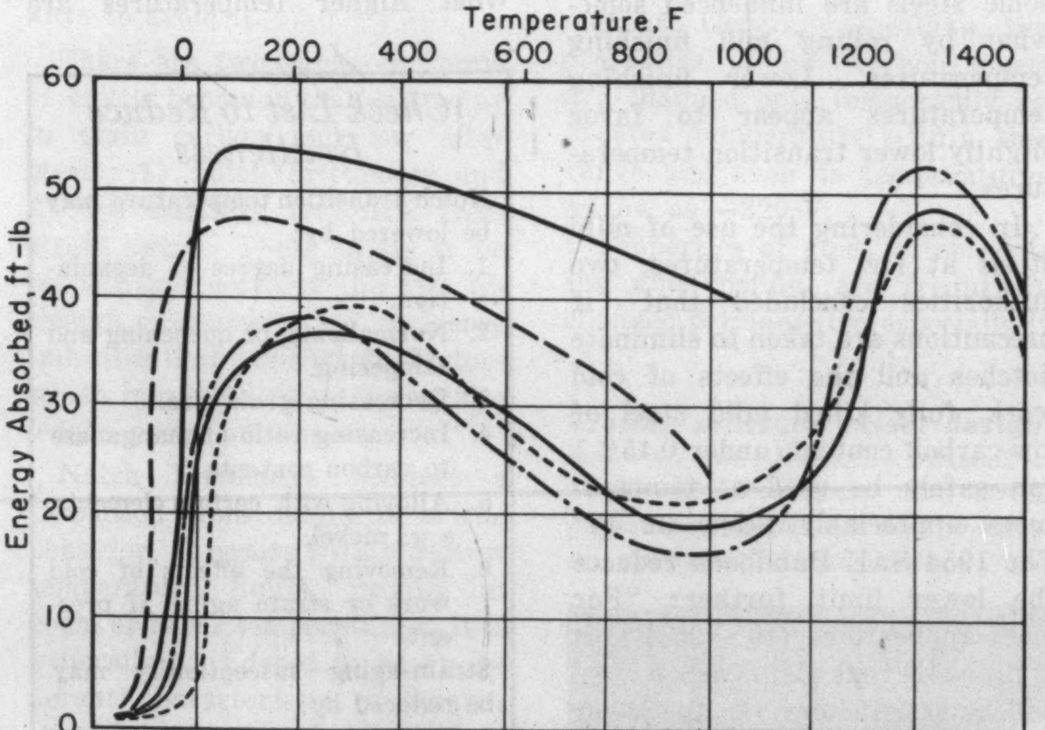
The tendency of a steel to fracture without appreciable deformation under pressures applied to a pressure vessel can exist not only because of the metallurgical properties of the steel, but also because of improper design or fabrication methods.

The problem of brittleness is closely related to that of stress concentration caused by notches or notch effects. The latter may be produced by surface scratches, flaws, weld defects, corrosion pits or other causes. Although notch effects and their danger are well understood by stress analysts, design engineers and most fabricators of pressure vessels, it is sometimes difficult to appreciate the importance of seemingly insignificant and invisible flaws in the material as possible sources of failure.

Welding produces local changes in metallographic structure of metals and sets up internal stresses which will be added to the mechanical stresses imposed by pressure on a vessel unless they are properly relieved by heat treatment. The necessity for relieving these stresses is well known and is especially important where brittleness may exist. However, stress relief procedure can be abused by hurrying. One of the dangers is that a vessel may be heated only to 1100 F, the lower limit of specified temperature range, and kept there for too short a time to permit a uniform elimination of stresses. More time at the temperature or slightly higher temperatures have been required in some instances to assure the relief of residual stresses.



Decrease in the modulus of elasticity is practically linear from room temperature to 600 F.



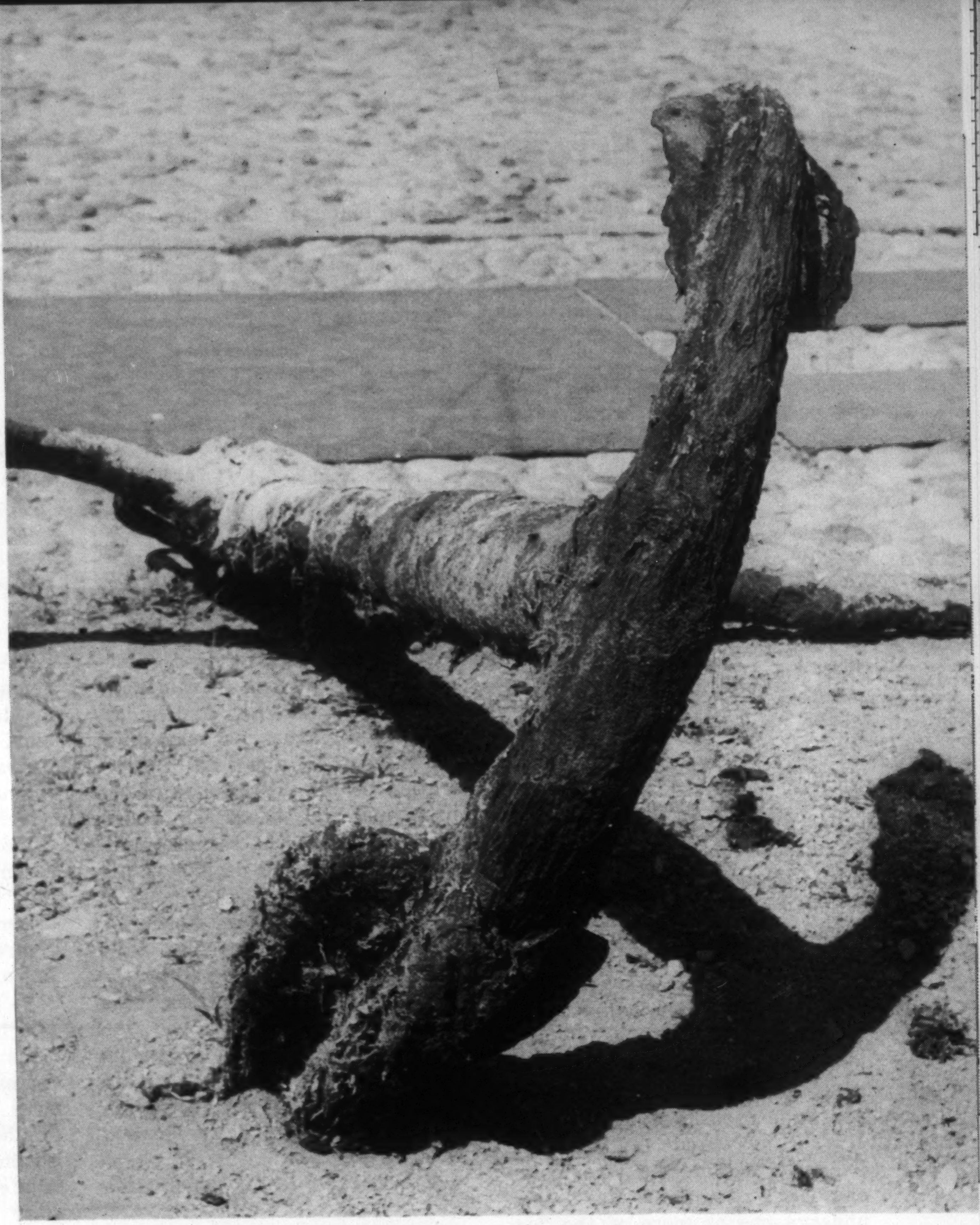
Impact properties of carbon and low alloy steels are characterized by sharp decreases in impact toughness with decrease in temperatures below normal. Curves show effect of steel making practice; transition temperature is lowest for Izett steel, highest for Bessemer steel.

Another danger in the fabrication of pressure vessels is careless inspection and resulting failure to detect stress raising flaws in the material, especially in the welds. Specification of a fine grain structure, fully killed steel or use of higher alloy steel is not a proper substitute for improper design, fabrication procedures or careless inspection. In some instances shot peening can be used to eliminate tensile stresses at the surface and to minimize the effect of surface flaws by putting the surface in compression.

Rough handling and careless use of tools during installation can produce points of stress concentration. Similarly, corrosion pits, such as those produced by electrolytic action, can be starting points for failures attributable to stress concentration and brittleness properties.

Fatigue of metals, produced, for example, by vibration from nearby machinery, is a factor that may lead to premature failure, especially when there are points of stress concentration produced by any of the conditions mentioned above. Pressure vessels, such as liquefied petroleum gas tanks that are carried on highway trucks, are subject to vibrations that may lead to fatigue failures.

In general, the inspector of pressure vessels, fabricated for use under outdoor atmospheric conditions, can do much to keep plain carbon and low alloy steels practical materials for such service by finding stress raising flaws and rejecting vessels in which they occur. Although brittleness can be minimized by proper steel making practice, unnecessary stress concentration can bring failure to the best of materials.



by **Russel W. Henke,**
Chief Mechanical Engineer,
Research & Development
Div., Badger Meter Mfg. Co.

Corrosion:

How it affects materials selection and design

MATERIALS & METHODS MANUAL No. 121

This is another in a series of comprehensive articles on engineering materials. These sections provide the reader with useful data on characteristics and uses of materials, parts and finishes.

Probably one of the most troublesome and costly, yet least generally understood or considered, parameters in design work is corrosion. Many corrosion problems encountered in the field could be reduced in magnitude, if not completely eliminated, by a more enlightened approach in the product planning and design stages. This manual covers:

- *Types of Corrosion*
- *Mechanisms of Corrosion*
- *Designing to Reduce Corrosion*

What is Corrosion?

■ Just what is corrosion? There are many ways to define these insidious phenomena. Some metallurgists or physical chemists will undertake the definition in terms of "free energy changes"; others, perhaps in terms of electrolytic or electrochemical terminology (there is one school of thought which holds, that all corrosion is fundamentally electrochemical in nature). A good layman's definition, in terms of results of, rather than mechanism of corrosion, might be expressed as:

> *The degradation of a material, with resultant reduction in usefulness for its application, due to inadvertent mechanical, chemical, or electrochemical action or a combination thereof.*

The author believes that this definition expresses, in a simple manner, the essential features of corrosion as the term is generally applied.

First, the material in question is degraded from some useful condition to a state of reduced usefulness. This can be illustrated by the rusting of steel structural members; the "freezing" of a valve due to deposition of corrosion product; or disintegration of a bolt or rivet. Note the emphasis on usefulness. A discarded tin can or junked length of pipe is hardly the object of a corrosion engineer's attentions. True, they undergo one or more of the "actions" associated with corrosion. As the term is used today, however, it connotes a reduction in usefulness of something as a result of one or more of the above "actions".

Secondly, the definition points out that the degrading action must be inadvertent. Many of the same phenomena described as corrosive when occurring inadvertently, are intentionally applied during certain processes, such as electroplating, anodizing, chemical milling, etching, etc. In these cases the phenomena are not considered corrosive because they are controlled to produce a desired result; to increase the usefulness of the material. They are corrosive only when uncontrolled—when they reduce its usefulness.

And, finally, the definition indicates the manner in which the degradation might occur; mechanically, chemically or electrochemically. These "actions", as they have been termed, will be the subjects of the remaining discussion.

Rate of Corrosion

Before proceeding to the discussion of corrosion phenomena, it might be worthwhile to outline the methods of expressing the magnitude of corrosive degradation. The two most commonly used systems are "ipy" and "mdd".

The first, inches per year, gives the measure of the rate of penetration of the corrosion into the base material based on linear measure, while the second, milligrams per square decimeter per day, is based on the rate of weight loss or gain per unit area. A third system, not yet fully defined, has been proposed by the author for rating pitting type corrosion.

These common rating systems infer that there are several manners in which the corrosion phenomena might be evidenced. Briefly, they are,

1. General over-all penetration into the surface, with resultant uniform reduction in thickness. This form may or may not result in a residue of corrosion products deposited on the surface. The rate of penetration is relatively slow, usually.
2. Localized, rapid penetration of the surface resulting in a relatively deep cavity. Generally results in perforation of the material in a much shorter period of time than would be required for penetration to the same depth under conditions of uniform corrosion. This is termed "pitting".
3. The corrosion outlined in points one and two above are generally associated with chemical or electrochemical types of corrosion. Under mechanical type of degradation we list erosion, impingement, and fretting corrosion, which can be rated by the same systems, but which leave a different kind of evidence of corrosive activity than the preceding classes, generally characterized by a directional roughening or wearing of the material.
4. Somewhat of a combination of chemical and mechanical actions is the phenomena known as "stress corrosion cracking". This class is evidenced by a cracking of the material as the result of a combination of stress and corrosive environment.

Types and Mechanisms of Corrosio

In order to design products to avoid or minimize corrosion, it is important that we understand the various types and mechanisms of corrosion. The classification and definition of the various types of corrosion given below is based on either the physical evidence of the corrosive action or is in terms of the action producing the corrosion. In some cases the evidence of, and the mechanism of, corrosion overlap so much as to prohibit separation in a definition.

Galvanic corrosion

This is one of the great broad classes of corrosion under which fall many of the familiar problems. Basically, galvanic corrosion occurs when two dissimilar metals are coupled together electrically in an electrolyte or conducting solution. The participants in a galvanic cell really constitute a battery. One of the members forms the cathode, the other an anode which is subject to degradation. (See Fig 1) An emf or potential

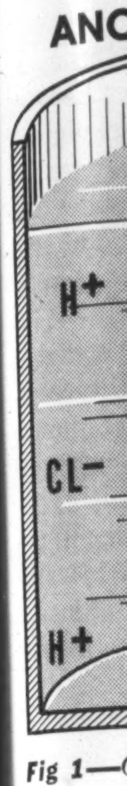


Fig 1—(

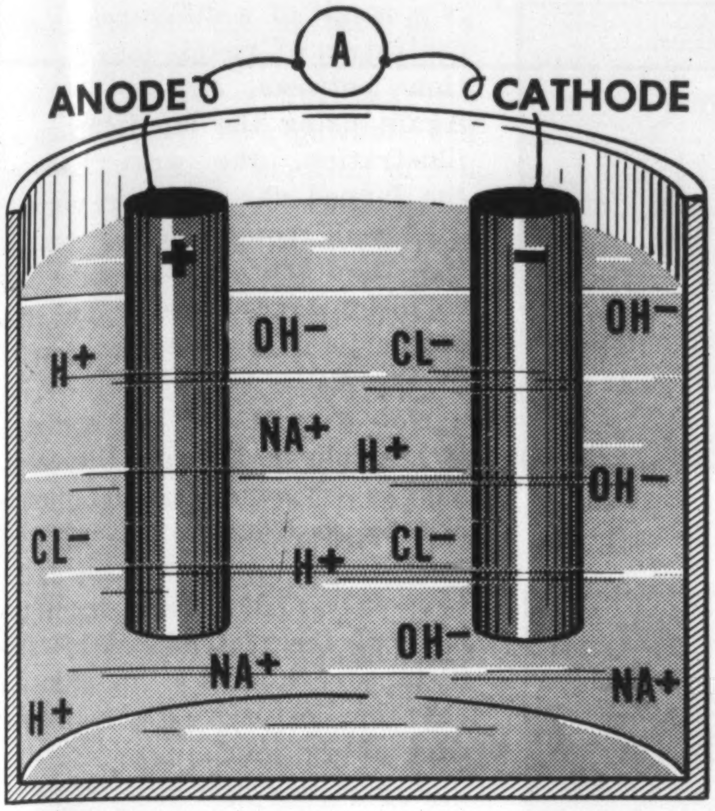
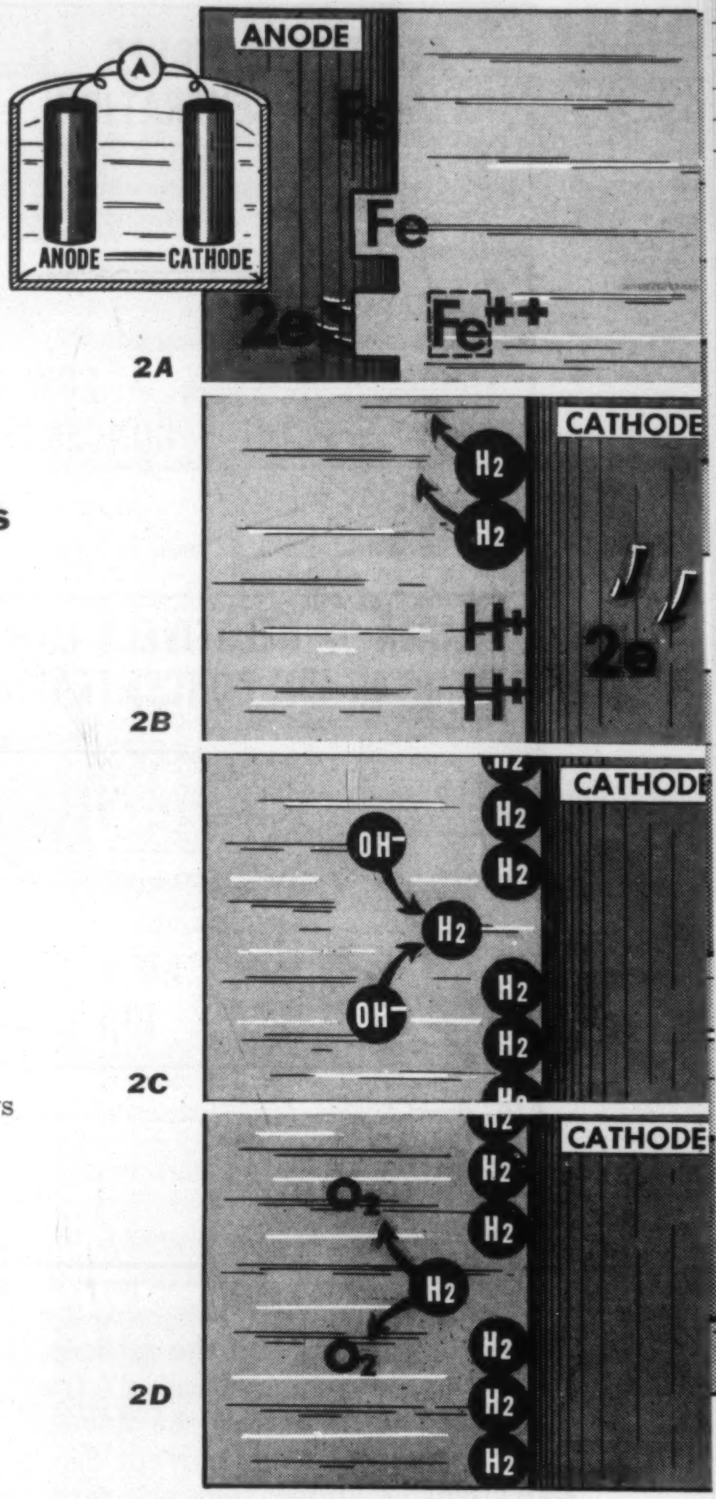


Fig 1—*Galvanic corrosion*

Fig 2—*A close-up look at the mechanism of galvanic corrosion.*



GALVANIC SERIES

Anodic End

Magnesium
Magnesium Alloys
Zinc
Aluminum 25
Cadmium
Steel or Iron
18:8 Stainless (active)
Lead
Tin
Nickel (active)
Brasses
Copper
Bronzes
Copper-Nickel Alloys
Monel
Nickel (passive)
18:8 Stainless (passive
Silver
Graphite
Gold

Cathodic End

difference between the anode (positive pole) and cathode (negative pole) exists in relation to their position in the galvanic series. The galvanic series is a table of the common metals and alloys arranged in such an order that any metal in the series will be anodic to any other metal below it, and cathodic to any metal above it in the series.

If the coupled metals are close together in the series, there will be a small potential difference and relatively little tendency toward galvanic or electrolytic corrosion. If the coupled metals are spread far apart in the series, the potential difference will be relatively great, and the tendency toward corrosion will be correspondingly increased.

Let's look at the mechanism of galvanic corrosion in a little more detail. The strip illustrating Fig 2 will help to explain the action. Iron is used as an example.

2A shows schematically the action at the surface of the anode. The iron atom detaches itself from the parent metal surface and passes into solution as the iron ion Fe^{++}. In doing so, it releases two electrons.

2B illustrates one of the reactions which can occur at the cathode. The two electrons released by the ion atom arrive via a connecting conductor at the cathode. Two hydrogen ions migrate to the cathode surface, "pick up" the electrons to form hydrogen atoms, then unite to form molecules of hydrogen gas. This gas must be removed if further corrosion is to take place.

2C illustrates a second cathodic reaction which can occur and which would help to prevent "cathodic polarization." The hydrogen gas molecule can combine with two hydroxyl ions, OH^-, to form water aoccording to the reaction:

$$2OH^- + H_2 \rightarrow 2H_2O$$

or

2D shows a third type of reaction which can occur. The oxygen combines with the hydrogen according to the reaction:

$$2H_2 + O_2 \rightarrow 2H_2O$$

and then prevents polarization by removing the hydrogen.

It should be remembered that these illustrations are schematic only and are not intended as a unique representation of the action.

The discussion indicates that the *anode* material is the one which is degraded or dissolved by electrolytic action in a galvanic cell.

The term, "current density", is used in relation to galvanic cell action. It can be described simply as the current per unit area of surface. When cathode

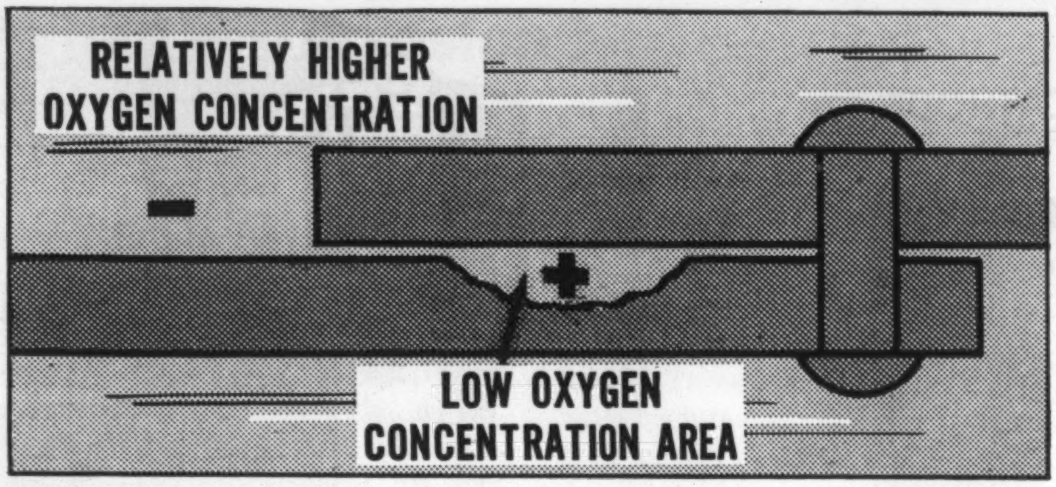

RELATIVELY HIGHER OXYGEN CONCENTRATION
—
+
LOW OXYGEN CONCENTRATION AREA

***Fig 3**—Crevice corrosion—oxygen concentration type.*

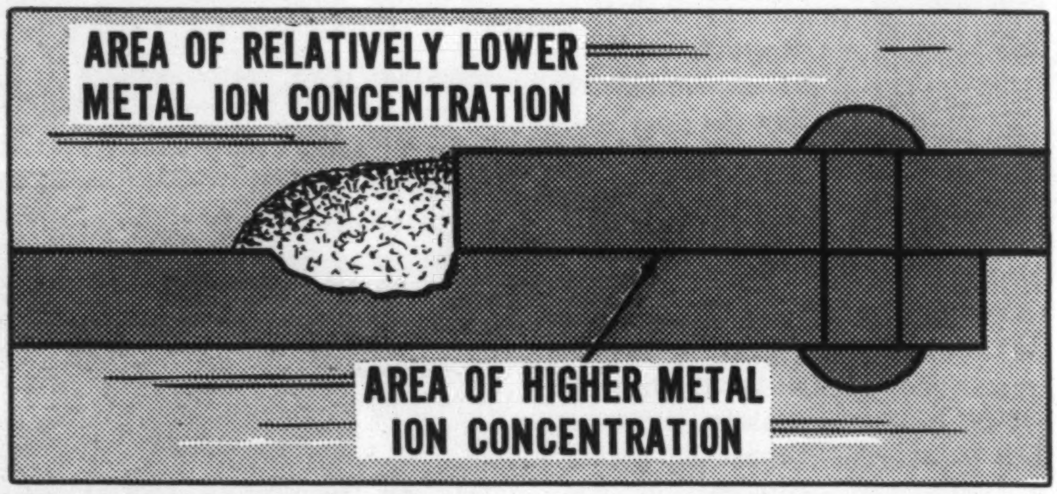

AREA OF RELATIVELY LOWER METAL ION CONCENTRATION
AREA OF HIGHER METAL ION CONCENTRATION

***Fig 4**—Crevice corrosion—metal ion concentration cell type (differential aeration).*

and anode are of equal areas, the cathodic and anodic current densities are equal. If, however, the anode is smaller than the cathode, the current which "leaves" the cathode must "enter" the anode, and, thus, the anodic current density will be higher than the cathodic. Since the anode is the disintegrating material, this leads to accelerated corrosion of the anode. This discussion leads to one of the cardinal rules in corrosion abatement:

Never couple large cathodic areas to small anodic areas.

Or, stated another way, don't couple small areas of metals high on the galvanic series with large areas of metals falling lower in the galvanic series. A typical fatal coupling would be aluminum and copper or brass. If it is necessary to utilize anodic-cathodic material combinations, it is recommended that they be electrically insulated from each other where practical.

The simple form of galvanic coupling just described is not difficult to analyze. This form of corrosion, however, acts in more subtle ways which are difficult to diagnose. These can be classed as special cases of galvanic corrosion and include oxygen concentration or differential aeration cell, metal ion concentration cell, crevice corrosion, passive-active cell.

Crevice corrosion is a term which could connote oxygen concentration, differential aeration, or metal ion concentration cell corrosion. In the case of the first two, the cell is a result of difference in concentration of dissolved oxygen or air between adjacent locations in a system. A lapped sheet metal joint is the classic illustration. The low oxygen area, i. e., the surface under the lap, is anodic to the areas of higher oxygen concentration. Corroding away of metal beneath the lap could be an indication of such a cell action (Fig 3).

The metal ion concentration cell is a result of a difference in concentration of metals ions in solution between adjacent locales. Again using the lap joint as an illustration, the area between the lapped sheets is presumably higher in metallic ion concentration than the areas outside. The corrosion takes place at the edge of the joint (anodic area); refer to Fig 4.

Note from Fig 3 and 4 that it is possible to identify the corrosion as oxygen cell or metallic ion cell by location of the corroded area. In the oxygen cell the corrosion takes place back from the edge of the plate a considerable distance, while in a metallic ion cell the corrosion occurs at the edge of the joint.

A passive-active cell is a case of meal coupling, but instead of being two dissimilar metals coupled, it consists of the same metal in two different states. Certain of the high alloys, in particular stainless steels, can exist in both the active and the passive states.

An alloy, such as stainless, is passive by virtue of an exceedingly tenacious oxide film on its surfaces. The tendency toward continued maintenance of this invisible protective film is so strong in most media that it is repaired, almost spontaneously, immediately after it is damaged. However, there are some media in which the film is destroyed, and the metal corrodes at an accelerated rate. This is the active stage. It is also possible to have cells set up in which the same material is in the active and passive states with resultant degradation of the anodic (active) areas.

As if the problem weren't complex enough, it has been theorized that it is possible to have anodic and cathodic areas adjacent to each other on the same surface of a metal. We do know that such impurities as nonmetallic inclusions in metals result in a galvanic cell action, as will such phenomena as inadvertent precipitation of carbides in grain boundaries during heat treating of a metal.

Deposits on the surface of a metal, such as dirt, tubercules, barnacles and other marine growths, result in a galvanic cell of the differential aeration or ion concentration type. The area below the deposit is anodic to the area surrounding it, and the resultant corrosion is characterized by a pit. (Fig 5).

Breaks in protective coatings, such as paint, plating, etc., are apt to result in pitting of the metal so exposed. This action is greatly accelerated where the break occurs over anodic material in a known couple. It is, therefore, not advisable to paint or otherwise coat the surface of a material when it is known that it will be coupled to a material cathodic to it. The resultant uniform corrosion of the anode, if left exposed, would be much less disastrous than the rapid penetration of it by pitting through breaks in a coating in many applications. Each case must, of course, be analyzed individually in this respect.

Chemical action

Fundamentally, this type of corrosion can be described as that in which the base material enters into direct combination with some element present in the corrosive media, with accompanying deposition of a corrosion product characteristic of the chemical union. There has been some doubt cast as to the entire validity of such a simple definition of this type of action. This is particularly true of the work done in support of the universal electrochemical theory. However, for our purposes this definition is adequate.

Dezincification

This type of corrosion has been characterized as peculiar to the higher zinc brasses, the alloys of less than 85% copper. It occurs as the solution of both copper and zinc with the immediate deposition of the copper in a spongy or honeycombed mass. It can also occur as the selective solution of the zinc, leaving the characteristic porous copper structure.

The residual metal is, of course, greatly weakened by dezincification. Leakage will occur in pressure vessels, castings or pipes.

The phenomenon is evidenced by two types of residual structures: 1) Uniform dezincification characterized by layers of degraded metal—one over the other. 2) Plug type dezincification resulting in local areas penetrating deeply into the surface in a direction perpendicular to it (Fig 6). The plug type would generally be expected to be the most active and destructive in that it results in penetration of the material in a shorter period of time.

The easiest method to combat dezincification is by the proper selection of materials. The lower zinc content brasses, or those containing tin or arsenic, show greater resistance to this type of corrosion than do other brasses.

Graphitization

Just as dezincification is peculiar to the high zinc brasses, graphitization is associated with cast iron in which graphite is dispersed in flake form.

The graphite is cathodic to the ion surrounding it. In certain kinds of waters, the iron goes into solution with great rapidity along the graphite-iron interfaces, leaving a porous graphite residual. This residue is soft—so soft that

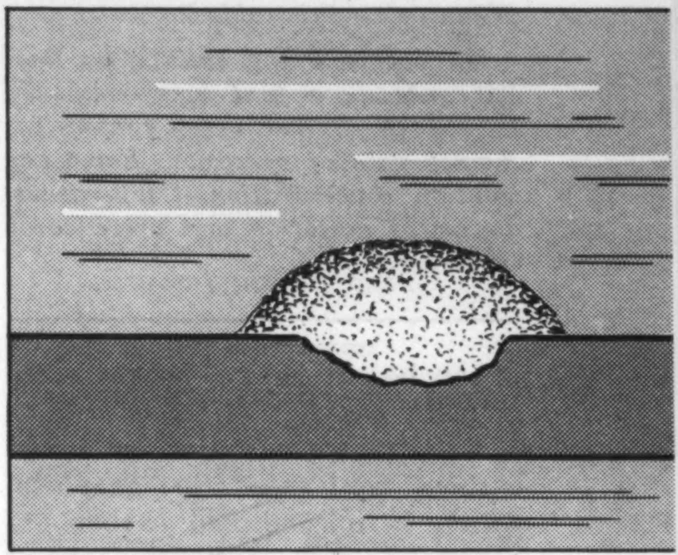


Fig 5—*Deposits on surface of metal cause corrosion of the ion concentration cell type.*

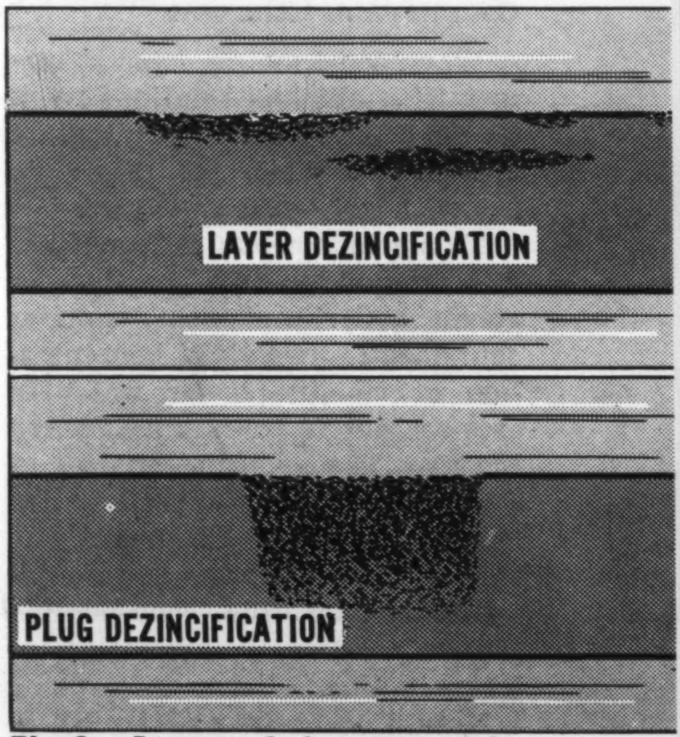


Fig 6—*Layer and plug types of dezincification.*

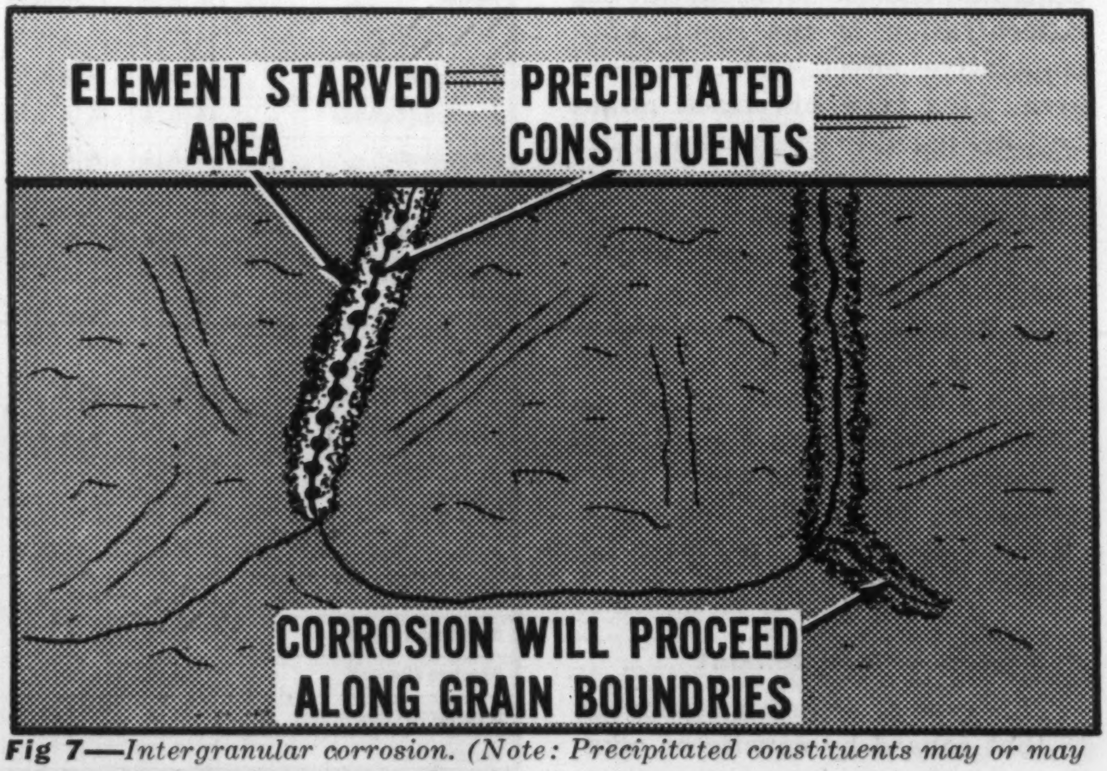

ELEMENT STARVED AREA
PRECIPITATED CONSTITUENTS
CORROSION WILL PROCEED ALONG GRAIN BOUNDRIES

Fig 7—*Intergranular corrosion. (Note: Precipitated constituents may or may not corrode depending on corrodent.)*

When using this table ➤

Do not take the ratings as final but only as a first approximation. In any given case many factors influence rate of corrosion. Some are solution concentration, temperature, degree of agitation and presence of impurities.

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it can be cut with a pocket knife in many cases.

As the proportion of combined carbon—contrasted to graphite, which is uncombined carbon—is increased, the tendency toward "graphitization" decreases.

Caustic-embrittlement

When some metals come in contact with alkaline solutions while under stress, either residual or applied tensile stresses, they show a tendency toward cracking.

This phenomenon is associated to a high degree with failure of steam boiler and heat transfer equipment, involving concentration of alkaline boiler water in crevices due to leaking seams and the like. The grain boundaries of steel, for example, exhibit an inherent chemical weakness. The failure, due to stresses and chemical attack of the concentrated caustic solution, is primarily intercrystalline.

Note that it is not the boiler water as a whole which is a concentrated caustic solution, but the concentration is the result of a cumulative effect in a stagnant area. This type of attack might be anticipated in chemical or other process equipment where caustic solutions are handled.

The actual mechanism of the attack is one of chemical degradation at the grain boundaries which, in the presence of stress, give a "notch effect" or act as stress raisers. The concentrated stresses at the weakened intercrystalline areas then cause mechanical failure of the material, evidenced by a crack in the metal.

Hydrogen embrittlement

This type of attack is analogous to that caused by caustic or alkaline solutions, except that it is

RATING CHART FOR CORROSION RESISTANCE

Rating

A—Excellent 0.006 ipy
B—Good 0.016 ipy
C—Fair 0.050 ipy
D—Unsatisfactory
O—No Data

	Hard rubber	Methyl methacrylate	Teflon	Polyvinyl chloride	Nylon 101 and 31	Carbon/graphite	Ceramic (alumina)	Natural rubber	Neoprene	Silicone rubber	Butyl	Buna N	Red brass 85-5-5-5	Admiralty bronze	Ampco metal (Al bronze)	Nickel silver	Monel	Hastelloy D	Cupro-nickel (Waukesha 20)	Stainless Steels 302	303	304	308	316	321	410	430	440	Cast Iron
Acetaldehyde	A	D	A	D	O	A	A	D	D	D	D	D			A		C		A	A	A	A	O	A		A			C
Acetic Acid, Pure	A	D	A	D	A	A	A	B	B	B	A	B	B	C	A	B	A		A	A	A	C	D	A	C	C	C	C	D
Acetic Anhydride	A	D	A	D	A	A	A	B	B	B	A	B	B	C	B	B	A		A	A	A	B	D	A	A	D	A	A	C
Acetone	A	D	A	D	A	A	A	B	B	B	A	B	A	A	A	A	A		A	A	A	A	O	A	A	A	A		A
Alcohols	A	C	A	B	A	A	A	B	B	B	A	B	A	A	A	A	A		A	A	A	A	O	A	A	A	A		C
Alum	A	O	A	A	A	A	A	A	A	B	A	A	B	B	B	B			A	A	C	C	D	A	C	C	C	C	O
Alumina	A	O	A	A	A	A	O	A	A	A	A	A	A	A	A	A													O
Aluminum Chloride	A	A	A	A	A	A	O	A	A	A	A	A	B	C	B	B	C		C	D	D	D	D	D	D	D	D	D	D
Aluminum Fluoride	O	O	A	B	A	A	O	A	A	A	A	A			B				A										D
Aluminum Hydroxide	A	A	A		A	A	O	A	A	A	A	A	A	A	A	A	A		A	A	A	A		A	A				A
Aluminum Sulfate	A	A	A	A	A	A	A	A	A	A	A	A	B	C	B	B	C	A	A	D	D	A	O	C	A	C	A	A	D
Amines	C	O	A		A	A	A	B	B	A	B	B			D		A		A	A	A	A	O	A	A	A	A	A	O
Ammonia (Anhydrous Liquid)	A	D	A		A	A	A	C	B	D	A	B	D	D	D	D	A		A	A	A	A	O	A	A	A	A	A	A
Ammonium Bicarbonate	A	A	A		A	A	O	A	A	A	A	A			D		A		A	A	A	A	A	A	A	A	A	A	C
Ammonium Carbonate	A	A	A		A	A	O	A	A	A	A	A			D		A		A	A	A	A	A	A	A	A	A	A	A
Ammonium Chloride	A	A	A	A	A	A	O	A	A	A	A	A	D	D	D	D	C	A	A	D	D	C	O	C	C	C	C	C	D
Ammonium Diphosphate	A	A	A		A	A	O	A	A	B	A	A			C		A	A	A	O	O	A		A			A		C
Ammonium Hydroxide	A	A	A	B	A	A	A	A	A	A	A	A	D	D	D	D	D	A	A	A	A			A					A
Ammonium Monophosphate	A	A	A		A	A	O	A	A	A	A	A			C		C	A	A	C	C	A	O	A	A	A	A	A	D
Ammonium Nitrate	A	O	A	A	A	A	A	A	A	A	A	A	D	D	C	D				O	O	A		A		A	A		O
Ammonium Sulfate	A	A	A	A	A	A	A	A	A	A	A	A	C	D	C	C	A	A	A	C	C	A	O	C	A	B	A	A	C
Ammonium Triphosphate	A	A	A		A	A	O	A	A	B	A	A			C		A	A	A	A	A			A					A
Ammonium Thiocyanate	A	O	A		A	A		A	A	B	A	A			O														
Amyl Acetate	A	D	A			A	O	D	D	D	D	C	A	A	A	A	A		A	C	C	A		A					C
Amyl Alcohol	A	O	A		A	A	O	A	A	C	A	A	A	A	A	A	A		A	A	A					A	A		
Amyl Chloride	A	O	A			A	O	D	D	D	D	D			A							A				B	B		
Aniline	A	D	A			A	A	O	O	O	O	O	C	C	C	C	A		A	A	A	A		A			A		A
Aniline Dyes	A	D	A			A	O	C	C	D	A	C	C	C	C	C	A		A	C	C			A					C
Aniline Oil	A	D	A			A	O	D	D	D	D	D	C	C	C	C	A		A	A	A			A					A
Antimony Chloride	A	O	A		A	A	D	B	B	A	B	B			O														
Antioxidants[a]	A	A	A		A	O	A	A	A	A	A	A			O														
Aromatic Hydrocarbons	D	D	A		A	A	A	D	D	D	D	C			A	A													
Arsenic Acid	A	O	A	A	A	A		A	A	A	A	A			C														
Arsenic Trichloride	A	O	A		A	A		A	A	A	O	A			D														
Asphalt	B	O	A		A	A	A	D	D	D	D	D	A	A	A	A													
Barium Carbonate	A	O	A		A	A	O	A	A	B	A	A	A	A	A	A													
Barium Chloride	A	A	A		A	A	A	A	A	B	A	A	B	C	B	B	C		C	C	C			C					C
Barium Hydroxide	A	A	A		A	A	O	A	A	B	A	A	A	A	A	A	A		A	A	A			A					A
Barium Sulfate	A	O	A		A	A	O	A	A	A	A	A	A	A	A	A						A		A	A		A		
Barium Sulfide	A	O	A		A	A	O	A	A	B	A	A	C	B	C	C						A							
Beer		D	A	A	A	A	O	A	A	A	A	A	A	A	A	A	C		A	A	A	A		A					D
Beet Sugar Liquors		O	A	O		A	O	A	A	A	A	A	A	A	A	A													
Benzene (Benzol)	B	D	A		A	A	A	D	D	D	D	C	A	A	A	A	A		A	A	A	A	O	A	A	A	A	A	A
Benzenesulfonic Acid		O	A			A	A	O	O	O	O	O			B	A													
Benzoic Acid	A	A	A		A	A	A	O	O	O	O	O	A	A	A	A	A		A	A	A	A		A	A	A	A	A	C

[a] *Aldol 1-naphthylamine, phenylnaphthylamine, etc.*

RATING CHART FOR CORROSION RESISTANCE (cont.)

Rating A—Excellent 0.006 ipy B—Good 0.016 ipy C—Fair 0.050 ipy D—Unsatisfactory O—No Data	Hard rubber	Methyl methacrylate	Teflon	Polyvinyl chloride	Nylon 101 and 31	Carbon/graphite	Ceramic (alumina)	Natural rubber	Neoprene	Silicone rubber	Butyl	Buna N	Red brass 85-5-5-5	Admiralty bronze	Ampco metal (Al bronze)	Nickel silver	Monel	Hastelloy D	Cupro-nickel (Waukesha 20)	Stainless Steels 302	303	304	308	316	321	410	430	440	Cast iron
Black Liquor Sulfate Process	A		A	B		A	O	A	A	A	A	A	C	D	C	C													
Bleaching Powder, Wet	A		A	B	A	A	A	A	A	A	A	A	B	B	B	B													
Boiler Compounds, pH 8.0	A	O	A		A	A	A	A	A	A	A	A			O	A													
Boiler Compounds, Acid Tannin	A	O	A		A	A	O	A	A	A	A	A			O	A													
Boiler Acid Phosphate Types	A	O	A			A	O	A	A	A	A	A			O	B													
Borax	A	O	A	O	A	A	O	A	A	A	A	A	A	A	A	A						A		A	A		A	A	
Bordeaux Mixture	A	O	A			A	O	O	A	O	O	A	A	A	O	A													
Boric Acid	A	A	A	O	A	A	A	A	A	A	A	A	A	A	A	A	A		A	A	A	A	A	A	A	A	A	A	D
Brine	A	A	A	A	A	A	A	A	A	A	A	A	B	B	A	B													
Bromine (Anhydrous Liquid)	D	D	A			O	O	D	D	D	D	D	B	C	O	B	D		D	D	D	D	O	D	D	D	D	D	D
Butadiene	D	O	A			A	O	D	B	D	D	A			A	B													
Butane		A	A			A	A	D	B	D	D	A	A	A	A	A													
Buttermilk	A	A	A		A	A	O	B	A	B	O	A			O	C	A		A	C	C	A		A	A	B	A		D
Butyl Alcohol	A	O	A		A	A	O	A	A	C	A	A	A	A	O	A													
Butyl Catechol Tert-		O	A			A	A	O	O	O	O	O			O	O													
Butyl-Cellosolve	C	O	A		A	A		D	D	D	D	D			O	B													
Butyl-p-Aminophenol		O	A			A	A	A	A	D	A	A			O	O													
Butylene		A	A			A	A	D	C	D	D	A			A	A													
Butyric Acid	A	A	A			A	O	A	A	A	A	A	B	B	A	B	A		A	C	C	A		A	A	A	A		D
Calcium Bisulfite	A	O	A	B	A		O	A	A	A	A	A	B	B	B	B													
Calcium Carbonate	A	O	A		A	A	A	A	A	A	A	A	A	A	O	A						A		A	A		A		
Calcium Chloride	A	A	A	A	A	A	O	A	A	A	A	A	B	B	O	B	A		A	D	D	C	O	C	C	D	D	D	C
Calcium Hydroxide	A	A	A		A	A	A	A	A	A	A	A	A	A	B	A	A		A	A	A	A		A	A				A
Calcium Hypochlorite	A	A	A	B	A	A	D	A	A	A	A	A	B	C	C	B	D		A	D	D	C		C	C	D	D	D	D
Calcium Sulfate	A	A	A		A	A	O	A	A	A	A	A	A	A	O	A	A		A	C	C	C	O	A	C	D	D	D	A
Calgon	A	A	A		A	A	A	A	A	A	A	A			O	B	A		A	A	A			A					D
Cane Sugar Sirups	A	O	A	O	A	A		A	A	A	A	A	A	A	O	A													
Carbolic Acid (Phenol)	B	A	A	A	D	A	O	A	A	A	A	A	B	B	A	B	A		A	A	A	A	O	A	A	A	A	A	D
Carbon Disulfide	D	A	A	D	A	A	A	D	D	D	C	D	B	A	C	B	C		A	A	A	A		A	A	A	A		A
Carbon Tetrachloride (Moist)	D	D	A	D	A	A	A	D	D	D	C	D	B	B	A	B	A		C	C	C	C	O	C	C	D	C	C	C
Carbonated Water	A	A	A		A	A	O	A	A	A	A	A	B	B	B	B						A		A	A	A	A		
Castor Oil	A	A	A	O	A	A	A	A	A	A	A	A	A	A	D	A	A		A	A	A			A					A
Catechol [c]		O	A			A	A	O	O	O	O	O			B	O													
China Wood Oil (Tung)	A	A	A		A	A	O	D	B	C	D	A			A	O	A		A	A	A			A					A
Chlorides, Organic	A	A	A			A	A	O	O	O	O	O			B	O	D		D	D	D			D					D
Chlorine (Anhydrous Liquid)	A	D	A	B	A	A	O	A	A	A	A	A	C	C	B	C	D		C	C	C	D	O	C	D	D	D	D	C
Chloroacetic Acid		D	A			A	O	D	D	B	D	D	B	C	B	B	D		D	D	D	D	O	D	D	D	D	D	D
Chlorobenzene		O	A			A	A	D	D	D	D	C			B	O						A		A	A		A		
Chloroform	D	D	A		A	A	A	D	D	D	D	D	A	A	A	A	A		A	A	A	A		A	A		A		C
Chlorox	A	A	A	A	A	A		A	A	A	A	A			D	O													
Chromic Acid	D	D	A	O		B	A	A	A	A	A	A	D	D	D	D	C		A	D	D	D	O	C	D	D	D	D	D
Cider	A	O	A		A	A	O	A	A	A	O	A	A	A	A	A													
Citric Acid	A	A	A	O	A	A	A	A	A	A	A	A	B	B	A	B	A		A	D	D	A	O	A	A	C	A	A	D
Coal Tar	D	O	A		A	A	A	D	C	D	D	B			B	O						A		A			A		
Coconut Oil	A	O	A	B	A	A		A	A	A	A	A			O	O													

[b] *Sodium hexametaphosphate; boiler treating compound.*
[c] *o-Dihydroxybenzene.*

(cont. on p. 126)

caused by hydrogen disintegrating the grain boundaries. The hydrogen penetration is a result of the reaction between the caustic and iron at temperature of the order of 1000 F. There is still much to be learned about the mechanism of hydrogen embrittlement.

Intergranular corrosion

Intergranular corrosion is characterized by a preferential attack along the grain boundaries in metals. Caustic and hydrogen embrittlement, just discussed, are examples of specific cases of intergranular corrosion.

Perhaps the major factor contributing to the increased susceptibility of grain boundaries to corrosion is the difference in composition between the material immediately adjacent to the boundary and that toward the crystal center. This is due, primarily, to precipitation of certain constituents, such as carbides, in the grain boundaries leaving an area "straved," in the precipitated component adjacent to the grain boundary (Fig 7). The result is actually like an alloy, or rather alloys, of two different compositions coexisting in the same crystal. The "starved" area is anodic to the "rich" area. When attack does occur, a galvanic cell action is set up, and the degradation of the anodic area—the grain boundary area—is really electrochemical in nature.

The best defense against intergranular attack would seem to be avoiding alloys and conditions which promote this type of corrosion, Proper treatment or stabilization of the material to prevent the inadvertent segregation of constituents in grain boundaries is also helpful.

Stress corrosion cracking

As previously defined, stress corrosion cracking is that form of degradation characterized by cracking of a material due to the combined action of corrosion and static tensile stresses, either residual or applied.

One of the interesting facts concerning this type of corrosion is that it is specific for the material involved and to the environment. That is, there is sufficient evidence to indicate that almost any metal, for example, will be subject to stress corrosion cracking in certain specific environments. Yet, the same set of conditions which causes cracking in one metal will not cause cracking in another.

Generally it can be expected that the static tensile stresses associated with failure are close to the yield strength of the material. To complicate the situation, however, there have been cases of failure at stresses considerably below the yield strength.

The mechanism of this class of corrosion failure is one of localized corrosion forming stress raisers in the presence of static stresses. These stress concentration points, such as pits and intergranular corrosion, cause magnification of the stress to a level where failure occurs in the form of cracking.

Iron and steel alloys appear to be subject to stress corrosion cracking in some nitrate solutions. The resulting cracks are usually intergranular. On the other hand, these same materials have been observed to exhibit transcrystalline cracking in certain gases under pressure, such as hydrogen cyanide, hydrogen sulfide and ammonium thiocyanate. (The latter failures may have had their origin in hydrogen embrittlement.

Certain stainless steels seem to be susceptible to stress corrosion cracking in the presence of chlorides, which is characterized by transcrystalline cracks. The ferritic stainless steels are less likely to exhibit this type of failure than are the austenitic alloys.

Moist ammoniacal atmospheres cause failure of some types of brasses. Presence of oxygen and carbon dioxide seems to contribute to the tendency and susceptibility to cracking increases with the level of tensile stress.

The higher zinc brasses are more likely to exhibit stress corrosion cracking. Alloys with 85-90% copper rarely fall victim to

RATING CHART FOR CORROSION RESISTANCE (cont.)

Rating

A—Excellent 0.006 ipy
B—Good 0.016 ipy
C—Fair 0.050 ipy
D—Unsatisfactory
O—No Data

Rating	Hard rubber	Methyl methacrylate	Teflon	Polyvinyl chloride	Nylon 101 and 31	Carbon/graphite	Ceramic (alumina)	Natural rubber	Neoprene	Silicone rubber	Butyl	Buna N	Red brass 85-5-5-5	Admiralty bronze	Ampco metal (Al bronze)	Nickel silver	Monel	Hastelloy D	Cupro-nickel (Waukesha 20)	Stainless Steels									Cast iron
																			302	303	304	308	316	321	410	430	440	
Coffee	A	A	A		A	A	O	A	A	A	O	A	A	A	A	A													
Copper Chloride	A	A	A	A	A	A	O	A	A	A	A	A	C	C	C	C	D		A	D	D	C		D	C		C		D
Copper Nitrate	A	O	A		A	A	A	A	A	A	C	A	C	C	C	C						A		A	A	A	A		
Copper Sulfate	A	A	A		A	A	A	A	A	A	C	A	B	B	D	B	C		A	C	C	A	O	A	A	A	A	A	D
Corn Oil	A	O	A		A	A	O	D	C	A	A	A	A	A	A	A													
Cornstarch Slurry	A	O	A		A	A	O	A	A	A	A	A			A	O													
Cottonseed Oil	A	A	A	B	A	A	O	A	A	A	A	A	A	A	A	A	A		A	A	A			A					A
Creosote		O	A	D	D	A	A	D	D	D	D	D	A	A	A	A						A		A	A				
Cresylic Acid		C	A		D	A	A	D	D	D	D	C	B	B	B	B	A		A	A	A			A					D
Cyclohexylamine		O	A			A	A	A	A	A	A	A			O	O													
Diacetone	A	O	A			A	A	C	C	C	C	C			A	O													
Diamylamine		O	A			A	A	A	A	A	A	A			D	O													
Dichloroethane		A	A			A	O	D	D	D	D	C			B	O	A		A	C	C			C					C
Dichloropentane		O	A			A	A	D	D	D	D	C			B	O													
Diesel Oil, Light	B	A	A		A	A	A	D	C	D	D	A			B	O													
Diethanolamine	A	O	A		A	A	A	A	A	B	A	A			D	O													
Diethylbenzene		O	A			A	A	D	D	D	D	D			A	O													
Diethyl Sulfate		O	A			A	A	B	B	C	B	B			A	O													
Diethylene Glycol	A	C	A		A	A	A	A	A	C	A	A			A	O	A		A	A	A			A					A
Dimethyl Phthalate		D	A			A	A	B	B	C	B	B			A	O													
Dioxane		O	A			A	A	A	A	D	A	A			O	O													
Dipentene		O	A			A	A	A	A	D	A	A			A	O													
Diphenyl (Biphenyl)		O	A			A	A	A	A	D	A	A			O	O													
Diphenyloxide		O	A			A	A	A	A	O	A	A			O	O													
Distilled Water	A	A	A		A	A	A	A	A	A	A	A			A		A		A	C	C			A					D
Doctor Solution		C	A			A	A	O	O	O	O	O			O		A		A	A	A			A					A
Enamel	A	A	A		A	A	A	O	O	O	O	O			B														
Ethanolamine	A	O	A		A	A	A	A	A	O	A	A			D														
Ether, Diethyl	A	D	A			A	A	O	C	O	C	A	A	A	A	A	A		A	A	A	A		A	A		A		C
Ether, Petroleum	A	D	A		A	A	A	O	B	O	C	A	A	A	A	A	A		A	A	A	A		A	A		A		C
Ethyl Acetate	A	D	A		A	A	A	D	D	D	D	C	A	A	A	A						A			A				
Ethyl Alcohol	A	D	A		A	A	A	A	A	B	A	A	A	A	A	A													
Ethylbenzene	A	D	A		A	A	A	O	O	O	O	C			A														
Ethyl Chloride	A	D	A		A	A	O	A	A	C	A	A	B	B	B	B	A		A	C	C	A		A	A				C
Ethyl Mercaptan	A	D	A			A	A	O	O	O	O	O			O														
Ethyl Sulfate	A	O	A		A	A	O	A	A	C	A	A			A														
Ethylene (Liquefied)	A	O	A			A	A	A	A	O	A	A			A														
Ethylene Dichloride	A	D	A		A	A	O	D	D	D	D	D			B														
Ethylene Glycol	A	C	A	O	A	A	A	B	B	B	A	B			A		A		A	A	A	A		A	A				A
Ethylene Oxide		O	A		A	A	A	D	D	D	D	D	A	A	O	A													
Fatty Acids	A	A	A	O	A	A	A	B	B	B	A	B			B		A		A	A	A	A	O	A	A	A	A	A	C
Ferric Chloride	A	A	A	O	A	A	O	A	A	A	A	A	D	D	D	D	D		C	D	D	D	O	D	D	D	D	D	D
Ferric Sulfate	A	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D		C	D	D	A	O	C	A	O	A	A	D
Ferrous Chloride	A	A	A		A	A	O	A	A	A	A	A	B	B	D	B	D		D	D	D			D					D

RATING CHART FOR CORROSION RESISTANCE (cont.)

Rating

A—Excellent 0.006 ipy
B—Good 0.016 ipy
C—Fair 0.050 ipy
D—Unsatisfactory
0—No Data

	Hard rubber	Methyl methacrylate	Teflon	Polyvinyl chloride	Nylon 101 and 31	Carbon/graphite	Ceramic (alumina)	Natural rubber	Neoprene	Silicone rubber	Butyl	Buna N	Red brass 85-5-5-5	Admiralty bronze	Ampco metal (Al bronze)	Nickel silver	Monel	Hastelloy D	Cupro-nickel (Waukesha 20)	Stainless Steels									Cast iron
																				302	303	304	308	316	321	410	430	440	
Ferrous Sulfate	A	A	A	A	A	A	A	A	A	A	A	A	B	B	D	B	D		D	D	D	A	0	D	A	A	A	A	D
Filter Aid [d]	A	A	A			A	A	0	0	0	0	0			B														
Fish Oil	A	0	A		A	A	A	D	B	C	B	A			B														
Fluoboric Acid		0	A	A		A		A	A	A	A	A			B									A					
Fluosilicic Acid		0	A	A		A		A	A	A	A	A			B														
Foam Killer No.33		0	A			A	A	0	0	0	0	0			B														
Formaldehyde	A	A	A	0	A	A	A	A	A	A	A	A	A	A	A	A	A		A	A	A	C	0	A	C	C	C	C	C
Formic Acid	A	A	A	B	A	A	0	A	A	A	A	A	B	B	A	A	C		A	C	C	C	0	C	C	D	D	D	D
Freon (Liquefied)	A	0	A		A	A	A	D	B	0	0	B	A	A	A	A													
Fruit Juices	A	0	A	0	A	A	0	A	A	A	A	A	B	B	B	B	A		A	C	C	A	C	C	A	A	A		D
Fuel Oil	B	A	A		A	A	0	D	B	C	D	A	A	A	A	A						A		A	A				
Fumaric Acid		0	A	0		A		A	A	A	A	A			B														
Furfural	A	0	A			A	A	D	D	D	D	D	A	A	A	A	A		A	A	A	A		A	A				A
Gallic Acid	A	0	A	0	A	A		A	A	A	A	A	A		A							A		A	A	A	A		
Gasoline	D	A	A		A	A	A	D	B	D	D	A	A	A	A	A						A		A	A	A	A		
Gasoline Antioxidant		A	A		A	A	A	0	0	0	0	0			B														
Gelatin	A	A	A		A	A	0	A	A	A	A	A	A	A	A	A	A		A	C	C	A		A			A		D
Glauber's Salt	A	0	A	A	A	A		A	A	A	A	A			A														
Glucose, Edible	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A		A	A	A			A					A
Glue	A	A	A	0	A	A	A	A	A	A	A	A	B	B	A	A	A		A	C	C	B		A	B		A		A
Glycerol	A	A	A	0	A	A	A	A	A	A	A	A	A	A	B	A	A		A	A	A	A		A	A	A	A		A
Grease, Molten	C	0	A			A	A	D	B	D	D	A			A														
Haering Water Treatments [g]		0	A			A	0	0	0	0	0	0			0														
Hagan Solution [h]		0	A			A	A	0	0	0	0	0			0														
Heptane (Liquefied)		A	A		A	A	A	A	A	D	A	A			A					A	A	A	0	A	A	A	A	A	
Hydrazine Hydrate		0	A			A		0	0	0	0	A			B														
Hydrobromic Acid	A	0	A	0		A	0	A	A	0	0	A	C	C	C	C	D		D	D	D			D					D
Hydrocarbons (Chlorinated)		D	A		A	A	A	D	D	D	D	C			B														
Hydrocarbons (Alkylated)		0	A			A	D	0	0	0	0	0			B														
Hydrocarbons (H_2SO_4)		0	A			A	A	0	0	0	0	0			0														
Hydrochloric Acid, Cold	A	A	A	B	A	A	D	A	C	A	A	A	C	C	C	C	D	A	D	D	D	D	0	D	D	D	D	D	D
Hydrocyanic Acid	A	0	A	0	A	A	0	A	A	0	0	A	D	D	D	D	A		A	A	A			A					C
Hydrofluoric Acid	B	0	A	B	A	A	D	B	A	0	0	B	C	D	B	C	C		C	D	D	D	D	D	D	D	D	D	D
Hydrofluosilicic Acid	A	0	A	0	A	A	0	A	0	0	0	A	B	B	C	B						D		D	D	D	D		D
Hydrogen Chloride (Gas)	A	0	A		A	A	0	0	C	A	A	A			B					D	D	D	0	D	D	D	D	D	
Hydrogen Peroxide	A	A	A	A	A	A	A	C	A	B	C	A	B	B	C	B	C		A	C	C	C	C	A	C	C	C	C	D
Hydrogen Sulfide Solution	A	A	A	0	A	A	0	A	A	0	0	A	D	C	D	D	C		A	C	C			A					D
Hydroquinone	A	D	A	0	A	A	A	A	0	B	0	A			B														
Hypochlorites (Sodium)	A	0	A		A	A	D	B	D	B	A	A			C														
Hypochlorous Acid	A	0	A	B	A	D		A	0	0	0	A			0														

(cont. on p. 128)

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[d] *Diatomaceous earth.*
[e] *Mixture of aliphatic esters.*
[f] *Solutions of n-butyl-p-aminophenol, isobutyl p-aminophenol, or di-sec-butyl p-aminophenol in isopropyl alcohol and methanol mixture.*
[g] *D. W. Haering & Co., Inc., P. O. Box 6037, San Antonio, Tex.*
[h] *Boiler treating compound, sodium phosphate type.*

this class of failure, while the bronzes are much less prone to be attacked.

In the aluminum system, pure aluminum is not subjected to failure. On the other hand, 12% zinc or 6% magnesium, and higher percentage, alloys have failed in atmospheric or tap water environments. The characteristic crack is intergranular.

Sensitivity to cracking of magnesium alloys increases with increase in aluminum and zinc content. The pure metal casting alloys and magnesium-manganese alloys show relative resistance. The cracking in this metal system is generally transcrystalline.

It should be noted that in many cases stress corrosion cracking is corollary to one of the other types of corrosive attack, such as intergranular corrosion, caustic embrittlement, etc. The corrosive action provides the stress raiser—the "notch effect"—and the static stress, so concentrated, causes the actual failure. It is a combined action.

The most obvious cure for stress corrosion cracking is, therefore, to reduce the excessive tensile stresses and/or remove the corrosive environment. These conditions are not, needless to say, always capable of fulfillment.

Corrosion fatigue

Corrosion fatigue is the dynamic analogue of stress corrosion cracking. In the case of stress corrosion cracking, the applied stress is defined as static. The applied stress in corrosion fatigue cases is cyclic.

The part played by corrosion in this type of degradation is similar to that which it plays in stress-corrosion cracking. Localized areas of corrosion act as stress raisers with a resultant decrease in the apparent endurance limit. The term, "apparent endurance limit," is used as a descriptive one since there can be no real endurance limit in a corrosive environment. One obvious reason for this is that the corrosion alone would cause failure if given a sufficient length of time. The simultaneous occurrence of cyclic stress and corrosion merely speeds up the process period.

One facet of the process which the occurrence of cyclic stressing amplifies is the rupturing or loosening of the protective film which frequently forms on the surface of materials exposed to corrosive environment. Normally the film tends to slow down corrosive action, but cyclic stressing disrupts it and, thus, contributes to accelerated corrosion.

Because of the ambiguity of the corrosion fatigue, in particular, the absence of a real endurance limit, published corrosion fatigue limits should be handled with caution. The only data which will be completely valid in a given situation will be that which was collected under identical circumstances. Other than this, judgment and experience are needed in applying general corrosion fatigue data to specific cases.

Impingement corrosion and erosion

These classes of corrosion are closely related and are associated with the impact of a liquid or gas medium on the surface of the material under attack. Degradation of these types might be expected in apparatus where fluids flow at relatively high velocity or conversely, which move at relatively high velocity through a fluid. Usual examples are heat exchange tubes, propellers, naval vessels, etc.

The difference between impingement corrosion and erosion corrosion is more a matter of degree than actual mechanism. It could be said in a general way that impingement corrosion is a moderate velocity phenomenon while erosion corrosion is a high velocity actor. Both are associated with corrosion of the base material and velocity of the corrosive media.

In impingement corrosion, the effect is one of removing the protective film from the surface of the material under attack, followed by the corrosive degradation of the exposed material. At least part of the mechanism of

RATING CHART FOR CORROSION RESISTANCE (Cont.)

Rating **A—Excellent 0.006 ipy** **B—Good 0.016 ipy** **C—Fair 0.050 ipy** **D—Unsatisfactory** **O—No Data**	**Hard rubber**	**Methyl methacrylate**	**Teflon**	**Polyvinyl chloride**	**Nylon 101 and 31**	**Carbon/graphite**	**Ceramic (alumina)**	**Natural rubber**	**Neoprene**	**Silicone rubber**	**Butyl**	**Buna N**	**Red brass 85-5-5-5**	**Admiralty bronze**	**Ampco metal (Al bronze)**	**Nickel silver**	**Monel**	**Hastelloy D**	**Cupro-nickel (Waukesha 20)**	**Stainless Steels**									**Cast iron**
																				302	**303**	**304**	**308**	**316**	**321**	**410**	**430**	**440**	
Inhibitors [i]		O	A		A	A	O	O	O	O	O	O			O														
Ink	A	A	A		C	A	A	O	O	O	O	O			O		A		A	C	C	B		A	B				D
Iodine	A	O	A		A	O	O	O	O	O	O	O			D					D	D	D		D	D	D	D	D	
Iodoform	A	O	A		A	A	O	O	O	O	O	O			B		A		A	A	A	A		A	A				C
Isobutane		A	A			A	A	D	C	D	D	A			A					D	D	D	O	A	D	D	D	D	
Isooctane		A	A			A	A	D	C	D	D	A			A														
Isopropyl Acetate	B	D	A			A		D	D	D	D	D			A														
Isopropyl Alcohol	A	O	A		A	A	A	A	A	B	A	A			A														
Isopropyl Ether	C	O	A			A		O	B	O	O	A			A														
Kerosine	B	A	A		A	A	A	C	C	D	D	A	A	A	A	A						A		A	A	A	A		
Ketchup	A	A	A		A	A	O	A	A	B	A	A			B		A		A	A	A	A		A	A	A	A		D
Ketones	A	D	A		A	A	A	C	D	D	A	D			B														
Lacquers and Lacquer Solvents	C	O	A		A	A	O	D	D	D	D	C	A	A	A	A	A		A	C	C			A					C
Lactic Acid	A	O	A	O	A	A	A	A	A	A	A	A	B	B	A	B	O		A	A	A	A	O	A	A	C	A	A	D
Lard	A	A	A		A	A	O	C	A	A	C	A			B							A		A	A	A	A		
Lead Acetate	A	O	A	O	A	A	A	A	A	A	A	A			O														
Lead Nitrate	A	O	A	O	A	A	A	A	A	A	A	A			O														
Lime Slurry	A	A	A	B	A	A	A	A	A	A	A	A	A	A	A	A													
Lime, Sulfur	A	A	A		A	A	O	A	A	A	A	A	C	B	B	C													
Linseed Oil	A	O	A		A	A	O	D	C	A	A	A	B	B	B	B	A		A	A	A	A		A	A	A	A		A
Magnesium Chloride	A	A	A	A	A	A	A	A	A	A	A	A	B	C	B	B	C		A	D	D	C	O	C	C	C	C	C	D
Magnesium Hydroxide	A	O	A	O	A	A	O	A	A	A	A	A	A	A	A	A													
Magnesium Oxide	A	O	A		A	A	A	A	A	A	A	A			A														
Magnesium Sulfate	A	A	A	A	A	A	O	A	A	A	A	A	A	A	A	A	A		A	A	A	A		A	A	A	A		A
Maleic Acid	A	O	A	O	A	A	A	A	A	A	A	A			B		D		A	A	A	B		A	B	B	B		D
Maleic Anhydride		O	A	O	A	A		A	A	A	A	A			O														
Malic Acid	A	O	A	O	A	A	O	A	A	A	A	A			B		A		A	C	C			A					D
Malt Beverages	A	O	A		A	A	O	A	A	A	A	A			A														
Mayonnaise	A	A	A		A	A	O	C	A	A	C	A			B		A		A	C	C	A		A	A				D
Melamine Resins	A	A	A		A	A	A	B	B	B	B	B			B		D		D	D	D			D					D
Mercaptobenzothiazole	A	O	A		A	A	A	C	A	D	C	C			O														
Mercury	A	O	A		A	A	A	A	A	A	A	A	D	D	D	D	C		A	A	A	A		A	A	A	A		
Mercury Salts	A	A	A	O	A	A	A	A	A	A	A	A	D	D	D	D	D		A	D	D	D		D	D	D	D		D
Methyl Acetate	A	D	A		A	A	A	D	D	D	D	D			A														
Methyl Acrylate		A	A			A	A	A	A	A	A	A			A														
Methyl Alcohol	A	D	A		A	A	A	A	A	B	A	A	A	A	A	A	A		A	A	A	A		A	A	A	A		A
Methyl Cellosolve		O	A		A	A	A	D	D	D	D	D			A														
Methyl Chloride, Dry		O	A		A	A	D	C	C	D	C	C	A	A	D	A	A		A	A	A			A					A
Methyl Ethyl Ketone	B	D	A		A	A	A	D	D	D	D	D			A														
Methyl Formate		D	A		A	A	A	B	B	B	B	B			A														
Methyl Isobutyl Ketone		D	A			A		D	D	D	D	D			A														
Milk	A	A	A		A	A	O	A	A	A	A	A	A	A	B	A	C		A	A	A	A		A	A	B	A		D
Mine Water		B	A	A		A	O	A	A	A	A	A	C	C	A	C													

[i] *Dialkylthioureas.*

(cont. on p. 130)

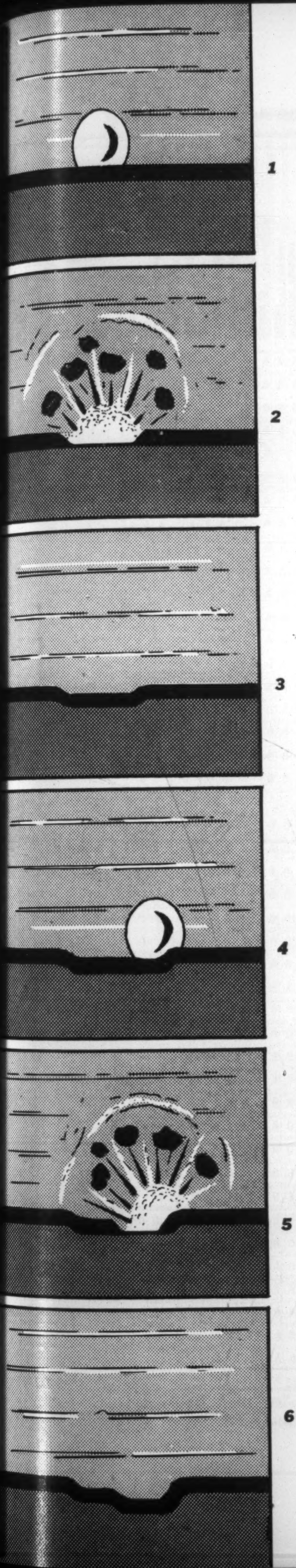

Fig 8—Steps in cavitation corrosion.
1—Bubble forms on protective film on metal.
2—Bubble collapses and destroys protective film.
3—Protective coating reforms over newly exposed metal.
4—New bubble forms at same location.
5—New bubble collapses destroying protective film.
6—Reforming of film drives pit deeper.

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the attack seems to center around an increased supply of oxygen to the surface, thus accelerating corrosion.

At high velocity, mechanical removal of the metal appears to occur. Actually, the action is associated with corrosion. The base material is apparently corroded and, the corrosion product being more easily removed, is eroded under the action of the high velocity media impinging on the surface. This hypothesis is supported by tests which have shown that erosion did not occur with a noncorrosive media which was free from insoluable solids. Obviously, if the fluid media has a relatively high insoluble solids content, it will be very abrasive at high velocity.

Fretting corrosion

Fretting corrosion is characterized by the pitting of opposite surfaces in close fitting parts due to relative vibratory motion. The tendency toward pitting seems to increase with closeness of fit and high surface finish.

The actual corrosion involved is thought to be one of the familiar types, such as galvanic corrosion, but the surface films or reactions which might halt the corrosive action in a "normal" action are continuously broken down under the vibratory motion. Corrosion can then occur at an uninterrupted and accelerated rate.

Fretting corrosion induces fatigue failure, causes malfunction due to loss of dimensional accuracy and destroys bearing surfaces. Fatigue failure can result because the pits and cracks which result from fretting corrosion act as stress raisers. This condition is further aggravated because the attack usually occurs at points of high loading.

Because fretting corrosion occurs under conditions of close fits between mating points, its occurrence causes loss of desired dimensional accuracy. One of the standard illustrations of fretting corrosion is that occuring between a bearing race and a shaft.

Cavitation corrosion

Cavitation corrosion is caused by the formation and subsequent sudden collapse of vapor bubbles against the surface of a material (Fig 8). This phenomenon is likely to occur in hydraulic systems where the liquid quickly passes from low to high pressure areas.

Where the bubbles collapse, the surface is pitted. Pitting is generally sharp edged, free from corrosion products, and the pitted area is clearly defined. While the action is primarily dynamic, the destruction of surface films appear to enter the picture, as has been the case in virtually all the mechanical corrosive actions.

Designing to Reduce Corrosion

The first sections of this manual have been presented as an introduction to corrosion for the engineer unfamiliar with its manifestations. It is obviously impossible to cover such a complex subject in great detail in so short a discourse. It is equally impractical to try to apply what is known about corrosion principles to the field of design in detail. Instead, general cases will be cited and discussed in light of what has been learned.

Members under stress

Much has been said about the combined effects of corrosive environment and stress, both static and dynamic. Situations involving stressed members would include:

Pressure vessels—Boilers, stills, autoclaves, reactors, cracking towers and heat exchanges.

Lines (Pipe)—Steam lines, hot water lines, condensor tubes, process lines and pipe lines.

Structural members — Beams, columns, guy wires, brackets, bolts, rivets, pins and welds.

Machine elements—Line shafts, spindles, arms, springs, transmission screws, pins and gears.

The primary requirements for the failure of members under combined stress and corrosion were corrosive media and static or residual *tensile* stresses in the case of stress corrosion cracking, and corrosive media with cyclic tensile stresses in the case of corrosion fatigue.

Since the emphasis is placed on tensile stresses, the first place to look in the analysis of a potential corrosion-stress situation is the members loaded in tension. This could be either straight tension due to externally applied loads or internal pressure; residued stresses due to heat treatment, working of the metal, etc.; or the tensile stresses associated with torsional loading of a member.

The members which might be subject to corrosion-stress failure will, in general, appear to be "safe" from a design standpoint. That is, the usual factor of safety will have been applied and the allowable stress so obtained utilized in conventional stress analysis calculations to determine the required section. Thus, the member would be expected to be loaded at a low enough level to perform its function satisfactorily.

Then inject the factor of corrosion into the picture. Depending on the circumstances, the corrosive action might result in deep pitting under lapped joints in a pressure vessel, intergranular attack on a shaft or along a weld bead. As the attack proceeds, "notch effect" increases, and the once nominal design stress approaches the yield stress. Cracking generally results. Propagation of the crack will continue under the interaction of the

RATING CHART FOR CORROSION RESISTANCE (cont.)

Rating

A—Excellent 0.006 ipy
B—Good 0.016 ipy
C—Fair 0.050 ipy
D—Unsatisfactory
O—No Data

	Hard rubber	Methyl methacrylate	Teflon	Polyvinyl chloride	Nylon 101 and 31	Carbon/graphite	Ceramic (alumina)	Natural rubber	Neoprene	Silicone rubber	Butyl	Buna N	Red brass 85-5-5-5	Admiralty bronze	Ampco metal (Al bronze)	Nickel silver	Monel	Hastelloy D	Cupro-nickel (Waukesha 20)	Stainless Steels									Cast iron
																				302	303	304	308	316	321	410	430	440	
Mineral Oil, U.S.P.	A	A	A	B	A	A	A	A	A	A	A	A			A														
Molasses	A	A	A		A	A	O	A	A	A	A	A			A		A		A	A	A			A					A
Monochloroacetic Acid		O	A			A	D	D	C	B	C	C			B														
Monochlorobenzene		D	A			A	O	D	D	D	D	D			A														
Nalco Solutions [j]		O	A			O	O	O	O	O	O	O			O														
Naphtha	C	O	A		A	A	A	D	C	D	D	A			A							A		A	A	A	A		
Naphthalene	B	O	A		A	A	A	D	D	D	D	D			A		A		A	A	A			A					A
Natural Gas	A	A	A		A	A	O	D	A	O	D	A			A														
Nickel Acetate	A	O	A	A	A	A		A	A	A	A	A			D														
Nickel Chloride	A	A	A	A	A	A	O	A	A	A	A	A			C		C		C	D	D	A		C	A				D
Nickel Nitrate	A	O	A	A	A	A		A	A	A	A	A			B														
Nickel Sulfate	A	O	A	A	A	A	A	A	A	A	A	A			B							A		A	A				
Nitric Acid (Crude)	D	O	A			D	A	D	D	D	D	D	D	D	D	D													
Nitric Acid 0–50%	B	D	A	A	B	D	A	B	B	B	A	B	D	D	D	D	D	A	A	D	D	A	O	C	A	C	C	C	D
Nitric Acid 50–100%	C	D	A	A	D	A	D	D	D	D	C	D	D	D	D	D	D	A	A	A	A	A	O	A	A	C	C	C	D
Nitrobenzene	D	O	A			A	O	D	D	D	D	D			C		A		A	A	A			A					C
Nordihydroguaiaretic Acid		O	A			O	A	O	O	O	O	O			O														
Nylon Salt		O	A			A	A	O	O	O	O	O			O														
Oakite [k]	A	A	A		A	A	O	O	O	D	O	O			O														
Octyl Alcohol	A	O	A		A	A		C	A	A	C	A			A														
Oleic Acid	A	A	A	O	A	A	A	B	B	B	B	B	B	B	A	B			A	A	A	A	O	A	A	A	A	A	
Oleum	A	D	A			D	A	D	D	O	D	D			O		D		A	C	C			A					D
Oleyl Alcohol	A	O	A			A	A	O	O	D	O	O			A														
Organic Acids	D	C	A		D	A	A	O	O	O	O	O			B			A											
Organic Esters	D	D	A		A	A	A	O	D	O	O	O			B														
Oxalic Acid	A	C	A	O	A	A	A	A	A	A	A	A	B	B	B	B	A		A	A	A	C	O	A	C	C	C	C	C
Paint	A	O	A		A	A	O	O	O	O	O	O			B														
Paint Vehicles (except Soya)	A	O	A		A	A	A	D	C	B	D	B			B														
Palm Oil	A	O	A		A	A	A	C	A	B	C	A			A							A		A	A		A		
Palmitic Acid	D	O	A	O	A	A	A	B	B	B	A	B	B	B	A	B													
Paraffin	A	D	A		A	A	A	D	C	B	D	A	A	A	A	A													
Paraffin Oil	B	A	A		A	A	A	D	C	B	D	A			A							A		A		A	A		
Paraformaldehyde	A	O	A		A	A	A	B	B	B	B	B			A														
Paraldehyde		O	A			A		B	B	B	B	B			A														
Parez 607 [l]		A	A			O	O	O	O	O	O	O			O		C		D	D	D			D					D
Pelargonic Acid		O	A			A	A	D	D	D	D	D			A														
Penicillin Solution		O	A			A	A	A	O	O	O	A			O														
Pentane		A	A			A	A	A	A	D	A	A			A														
Phenol	A	D	A		D	A	A	B	B	B	A	B			A		A		A	A	A	C	O	A	C	C	C	C	D
Phenolsulfonic Acid		O	A		D	O	A	D	D	O	D	D			B														
Phoscaloid [m]		O	A			O	A	O	O	O	O	O			O														

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[j] *Cation exchanger, zeolite or sodium aluminosilicate type.*
[k] *Metal cleaner, Oakite Products, Inc., 46-A Rector St., New York, N. Y.*
[l] *Resin, American Cyanamid Co.*
[m] *Water-treating compound, Cyrus Wm. Rice & Co., Pittsburgh, Pa.*

(cont. on p. 131)

RATING CHART FOR CORROSION RESISTANCE (cont.)

Rating A—Excellent 0.006 ipy B—Good 0.016 ipy C—Fair 0.050 ipy D—Unsatisfactory O—No Data	Hard rubber	Methyl methacrylate	Teflon	Polyvinyl chloride	Nylon 101 and 31	Carbon/graphite	Ceramic (alumina)	Natural rubber	Neoprene	Silicone rubber	Butyl	Buna N	Red brass 85-5-5-5	Admiralty bronze	Ampco metal (Al bronze)	Nickel silver	Monel	Hastelloy D	Cupro-nickel (Waukesha 20)	Stainless Steels									Cast iron
																				302	303	304	308	316	321	410	430	440	
Phosphoric Acid (Crude)	A	O	A			A	A	C	C	B	C	C	C	C	A	C	C	A	A	D	D	A	O	C	A	C	C	C	D
Phosphoric acid (0–45%)	A	O	A	A		A	A	B	B	B	A	B	C	C	C	C	C	A	A	C	C	A	O	D	A	C	C	C	D
Phosphoric Acid (>45%)	B	O	A	A		A	A	B	B	B	A	B	C	C	C	C	C	A	A	C	C	A	O	A	A	C	C	C	D
Phosphorus, Molten		O	A			A	A	O	O	O	O	O			O														
Phthalic Acid		O	A		A	A	A	C	C	B	C	C			B														
Phthalic Anhydride		O	A		A	A	A	C	C	B	C	C			B														
Picric Acid, Molten		O	A			A	O	C	C	C	C	C			D		D		A	A	A	A		A	A		A		A
Pine Oil	A	O	A		A	A	A	C	A	B	C	A			A							A		A	A		A		
Pitch	B	O	A		A	A	A	C	C	D	C	C			B														
Plating Solutions	C	A	A	A	A			A	A	A	A	A			O														
Potassium Alum	A	O	A		A	A	A	A	A	A	A	A			A														
Potassium Antimonate	A	O	A	A	A	A		A	A	A	A	A			O														
Potassium Bisulfite	A	O	A	B	A	A		A	A	A	A	A			B														
Potassium Bromide	A	A	A		A	A	O	A	A	A	A	A			O		C		A	C	C	B		C	B				C
Potassium Carbonate	A	A	A	A	A	A	O	A	A	A	A	A	B	B	B	A	A		A	A	A	A		A	A		A		A
Potassium Chlorate	A	O	A	O	A	A		A	A	A	A	A			C							A		A	A		A		
Potassium Chloride	A	A	A	A	A	A	O	A	A	A	A	A	B	B	A	B	A		A	D	D	A		C	A		A		A
Potassium Chromate	A	O	A		A	A	O	A	A	A	A	A	A	A	A	A													
Potassium Cyanide	A	A	A	O	A	A	O	A	A	A	A	A	D	D	D	D	A		A	A	A			A					A
Potassium Diphosphate	A	A	A		A	A	A	A	A	A	A	A			B		A		A	A	A			A					A
Potassium Hydroxide	A	C	A		A	A	O	A	A	A	A	A	B	B	C	A	A		A	A	A	A		A	A		A		C
Potassium Iodide	A	O	A		A	A	A	A	A	A	A	A			B														
Potassium Monophosphates	A	A	A		A	A	A	A	A	A	A	A			A		A		A	A	A			A					D
Potassium Permanganate	A	O	A		A	A	A	A	A	A	A	A			C							A		A	A		A		
Potassium Phosphates (Acid)	A	O	A		A	A	A	A	A	A	A	A			B														
Potassium Phosphates (Alkaline)	A	O	A		A	A	A	A	A	A	A	A			A														
Potassium Sulfate	A	A	A	A	A	A	O	A	A	A	A	A	A	A	A	A	A		A	A	A	A		A	A	A	A		A
Potassium Triphosphate	A	A	A		A	A	A	A	A	A	A	A			B		A		A	A	A			A					A
Prestone	A	O	A		A	A	A	B	B	D	B	A			A														
Propane (Liquefied)		O	A			A	A	D	C	B	D	A	A	A	A	A													
Propene (Liquefied)		O	A			A	A	O	O	O	O	O			A														
Propylene dichloride		O	A			A	A	D	D	B	D	D			B														
Pyrethrum Solution		O	A			A	A	B	B	A	B	B			O														
Pyridine		O	A			A	A	O	D	O	O	O			O					D	D			D			D		
Pyrogallic Acid	A	A	A			A	O	O	O	O	O	O			O		A		A	C	C	A		A	A		A		C
Quasol 80[a]		O	A			O	A	O	O	O	O	O			O														
Quebracho (Tannin)	A	O	A			O	A	A	A	A	A	A			O														
Rayon Spin Bath		O	A		A	A	O	O	O	O	O	O			B					C				C					
Resorcinol	A	O	A			A	A	O	O	O	O	O			B														
Rosin (Emulsion)	A	O	A		A	A	A	O	O	O	O	O			A							A		A	A		A		
Rosin (Molten)		O	A			O	A	O	O	O	O	O	A	A	A	A						A		A	A		A		
Rustang[b]		O	A			O	A	O	O	O	O	O			O														

[a] *Metal cleaner, Quaker Chemical Products Corp., Conshohocken, Pa.*
[b] *Boiler treating compound, Feedwaters, Inc., New York, N. Y.*

(cont. on p. 132)

corrosive media and tensile stress until such time as the effective area sustaining the load reaches a critical value and the member fractures.

In case of cyclic stressing, the situation is more critical since each reapplication of the load results in a tendency for the crack to progress farther through the member. This is responsible for the wavy pattern in the fractured section frequently associated with this type of failure. When the crack has progressed far enough into the loaded member, the area left is insufficient to sustain the applied load, and the next loading cycle causes the member to fail in a brittle manner. This, incidentally, is characteristic of fatigue failures in general. There is a wavy area in the fractured section which evidences the crack propagation, and then an area exhibiting the crystalline appearance of a brittle fracture.

The corrosion fatigue failure, then, is characterized by an initial design stress of a safe level which is eventually raised to a failure level by the virtue of the corrosive attack.

In approaching the problem from a design analysis standpoint:

1. Ascertain the probable severity of the corrosive environment to which the member or structure will be exposed.
    - a. Atmospheric
    - b. Fumes from processes, etc.
    - c. High temperatures
    - d. Direct contact with corrosive media, such as acids, alkalies
    - e. Possible galvanic coupling
2. Determine which member will be loaded in tension and manner of loading.
    - a. Static
        - 1) Pressure vessel
        - 2) Structural member
        - 3) **Torsion member**
        - 4) Fastener (bolt, rivet)
        - 5) Weld area
        - 6) Cold worked area
    - b. Dynamic
        - 1) Rotating shaft
        - 2) Gears, sprockets
        - 3) Machine arms
        - 4) Springs, dynamic

5) Keys, pins, splines

3. Make an initial determination of the approximate stress level at which the member is or will be operating.

Armed with information from the above analysis, the designer will be in a position to directly attack the problem.

First will be the selection of the proper material to withstand the known corrosive environment. This can be handled best with the assistance of one of the handbooks listed in the bibliography accompanying this discussion. The material selection will be based not only upon corrosion resistance, but upon the economics of the situation, the type of application, the available forms of the material, required or available fabrication methods and required service life as well. Here, as in any other design situation, the engineering approach requires that the material be selected which just satisfies all the requirements of the application. To utilize a material which more than fills the bill is poor engineering practice.

After the best material selection has been made, the configuration of the member(s) should be considered.

In vessels or members which will come in direct contact with corrosive media, remember:

1. Avoid lapped joints, especially riveted, where a slight separation of the plates will provide a crevice where a concentration cell action could start.

2. Be sure that welds do not result in an unfavorable microstructure, particularly precipitation of constituents in grain boundaries. If such precipitation does occur, specify a subsequent solution heat treatment to return these constituents to their proper state.

3. Fasteners are particularly vulnerable in some applications. Bolt and rivet heads or nuts and washers provide ideal focal points for concentration cell type attack. It may be prudent to consider a sealer under the head or nut of a bolt to prevent seepage of corrosive media.

4. Check to see if some area of

RATING CHART FOR CORROSION RESISTANCE (cont.)

Rating

A—Excellent 0.006 ipy
B—Good 0.016 ipy
C—Fair 0.050 ipy
D—Unsatisfactory
O—No Data

																			Stainless Steels									
	Hard rubber	**Methyl methacrylate**	**Teflon**	**Polyvinyl chloride**	**Nylon 101 and 31**	**Carbon/graphite**	**Ceramic (alumina)**	**Natural rubber**	**Neoprene**	**Silicone rubber**	**Butyl**	**Buna N**	**Red brass 85-5-5-5**	**Admiralty bronze**	**Ampco metal (Al bronze)**	**Nickel silver**	**Monel**	**Hastelloy D**	**Cupro-nickel (Waukesha 20)**	**302**	**303**	**304**	**308**	**316**	**321**	**410**	**430**	**440**	***Cast iron***
Salicylic Acid	A	O	A	O	A	A	A	A	A	A	A	A			B														
Santobrite [p]	A	O	A		A	A	A	C	C	C	C	C			A														
Santomerse [q]	A	O	A		A	O	A	O	O	D	O	O			O														
Santophen [r]	A	O	A		A	O	A	O	O	O	O	O			O														
Santosite [s]	A	O	A		A	O	A	O	O	O	O	O			O														
Sea Water	A	A	A	A	A	A	O	A	A	A	A	A	B	A	A	A						A		A	A		C		
Shellac	A	O			A	A	O	O	O	O	O	O			A														
Silicon Tetrachloride		O	A			A	A	D	D	O	O	D			B														
Silver nitrate	A	O	A		A	A	A	C	C	A	B	C	D	D	D	D						A		A	A		A		
Sizing (Acid)		O	A			A	A	B	B	A	B	B			O														
Sizing (Alkaline)		O	A			A	A	B	B	A	B	B			B														
Soap (Molten)	A	A	A		A	A	O	D	C	A	B	A	A	A	A	A	A			A	A	A		A	A		A		A
Sodium Acetate	A	A	A		A	A	O	B	B	B	B	B			A		A			C	C	A		A	A		A		C
Sodium Acid Sulfate	A	O	A		A	A	A	A	A	B	A	A			B														
Sodium Aluminate	A	A	A		A	A	A	A	A	A	A	A			A		A			A	A			A					A
Sodium Bicarbonate	A	A	A		A	A	A	A	A	A	A	A	B	B	A	A	A			A	A	A		A	A	A	A		C
Sodium Bisulfate	A	A	A		A	A	O	A	A	A	A	A	B	B	A	A	C			D	D	B		D	B	C			D
Sodium Bisulfite	A	A	A	B	A	O	O	A	A	A	A	A	B	B	B	A	C			C	C			A					D
Sodium Borate	A	O	A		A	A	A	A	A	A	A	A			A														
Sodium Carbonate	A	A	A	A	A	A	O	A	A	A	A	A	B	B	B	A	A			A	A	A	D	A	A	A	A	A	A
Sodium Chloride	A	A	A	A	A	A	A	A	A	A	A	A	B	A	A	A	A			D	D	C	O	C	C	C	C	C	A
Sodium Chromate	A	O	A		A	A	A	A	A	A	A	A	A	A	A	A													
Sodium Cyanide	A	A	A		A	A	A	A	A	A	A	A	D	D	D	D	A			A	A			A					A
Sodium Dichromate	A	O	A		A	A	A	A	A	A	A	A			B														
Sodium Fluoride	A	O	A		A	A	A	O	O	A	O	O			B							B		A	B		C		
Sodium Hydroxide (0–20%)	A	C	A	B	A	A	A	A	A	A	A	A	B	B	A	A	A			A	A	A	O	A	A	D	A	A	A
Sodium Hydroxide (20% or Hot)	A	D	A	B	A	A	D	A	A	A	A	A	B	B	A	A	A			A	A	A	O	A	A	D	C	A	C
Sodium Hypochlorite	A	A	A		A	A	D	C	D	A	C	C	C	C	C	B	A			D	D	C	B	C	C	D	D	D	D
Sodium Hyposulfite	A	O	A		A	A	A	A	A	A	A	A			O							C		B	C		C		
Sodium Diphosphate	A	A	A		A	A	A	A	A	A	A	A			B		A		A	A	A			A					A
Sodium Meta Phosphate	A	A	A		A	A	A	A	C	A	A	A			A		A		A	A	A			A					D
Sodium Metasilicate	A	O	A		A	A	A	A	A	A	A	A			A														
Sodium Methylate		O	A			A	A	A	C	B	A	A			A														
Sodium Monophosphate	A	A	A		A	A	A	A	A	A	A	A	B	B	B	A	A		A	C	C			A					D
Sodium Napthsulfonate		O	A			A	A	C	C	C	C	C			A														
Sodium Nitrate	A	A	A		A	A	A	A	A	A	A	A	B	B	B	B	A		A	A	A	A	O	A	A	A	A	A	A
Sodium Nitrite	A	O	A		A	A	A	A	A	A	A	A			B														
Sodium Orthosilicate	A	O	A		A	A	A	A	A	A	A	A			A														
Sodium Perborate	A	C	A	O	A	A	O	A	A	A	A	A			A		A		A	C	C			A					C
Sodium Peroxide	A	C	A		A	O	A	A	A	A	A	A	C	C	C	C	A		A	A	A			A					C
Sodium Plumbite		O	A		A	A	A	O	O	O	O	O			O														
Sodium Polyphosphate	A	A	A		A	A	A	A	A	A	A	A			B		A		A	A	A			A					D
Sodium Pyrophosphate	A	O	A		A	A	A	A	A	A	A	A			B														
Sodium Resinate		O	A		A	A	A	A	A	A	A	A			A														
Sodium Silicate	A	A	A		A	A	A	A	A	A	A	A	A	A	A	A	A		A	A	A			A					A

[p] *Sodium pentachlorophenate.*
[q] *Salts of homologous substituted aromatic sulfonic acids.*
[r] *Various benzyl- or chlorophenols.*
[s] *Anhydrous sodium sulfate.*

(cont. on p. 133)

RATING CHART FOR CORROSION RESISTANCE (cont.)

Rating A—Excellent 0.006 ipy B—Good 0.016 ipy C—Fair 0.050 ipy D—Unsatisfactory 0—No Data	Hard rubber	Methyl methacrylate	Teflon	Polyvinyl chloride	Nylon 101 and 31	Carbon/graphite	Ceramic (alumina)	Natural rubber	Neoprene	Silicone rubber	Butyl	Buna N	Red brass 85-5-5-5	Admiralty bronze	Ampco metal (Al bronze)	Nickel silver	Monel	Hastelloy D	Cupro-nickel (Waukesha 20)	Stainless Steels									Cast iron
																				302	303	304	308	316	321	410	430	440	
Sodium Silicofluoride		O	A		A	A	A	O	O	O	O	O			B														
Sodium Sulphate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A		A	A	A	A	O	A	A	A	A	A	A
Sodium Sulphide	A	A	A		A	A	O	A	A	A	A	A	C	C	D	C	A		A	C	C	A	O	A	A	A	A	A	A
Sodium Sulphite	A	A	A		A	A	A	A	A	A	A	A	B	B	B	B	A		A	A	A	A	O	A	A	C	C	C	A
Sodium Tetraborate	A	A	A		A	A	O	A	A	A	A	A			A		A		A	A	A			A					A
Sodium Tetraphosphate	A	O	A		A	A	A	A	A	A	A	A			B														
Sodium Thiosulfate	A	A	A		A	A	A	A	A	A	A	A	C	B	C	C	A		A	A	A	A	O	A	A	A	A	A	C
Sodium Triphosphate	A	A	A	A	A	A	A	A	A	A	A	A			B		A	A	A	A	A			A					A
Soybean Oil	A	O	A		A	A	A	O	A	B	A	A			A							A		A	A		A		
Starch	A	A	A		A	A	A	A	A	A	A	A			O		A		A	A	A			A					C
Steam Condensate	A	A	A		A	A	A	A	A	A	A	A	A	A	O	A													
Stearic acid	A	A	A		A	A	O	C	A	C	C	A	B	B	O	B			A	A	A	A	O	A	A	A	A	A	
Styrene		D	A			A	A	B	B	D	B	B			O														
Sugar Solutions	A	A	A		A	A	O	A	A	A	A	A			O		A		A	A	A	A		A	A	A	A		A
Sulphonyl Chloride		O	A			A	A	D	C	O	D	C	B		O							D		D	D	D	D		
Sulphur (Molten)	B	D	A		A	A	O	D	D	O	D	D	D	D	C	D	A		A	C	C	C	O	A	C	C	C	C	A
Sulphur Chloride	B	O	A		A	A	O	D	D	O	D	D	A	A	D	A	C		A	D	D			D					D
Sulphur Dioxide (Anhydrous)	A	O	A	B	A	A	A	A	A	A	A	A	B	B	B	C			A	C	C	C	O	C	C	C	C	C	
Sulphur Trioxide (Dry)	A	O	A		A	D	A	O	O	O	O	O	A	A	A	A													
Sulphuric Acid (0–10%)	A	A	A	A	A	A	A	B	B	B	A	B	B	C	A	B	C	A	A	D	D	A	O	D	C	D	D	O	D
Sulphuric Acid (10–90%)	B	D	A		C	A	A	D	A	D	D	D	C	C	B	C	D	A	A	D	D	D	O	D	C	D	C	O	D
Sulphuric Acid (90–95%)	D	D	A		D	A	A	D	D	C	D	D	B	C	D	B	D	A	C	D	D	A	O	O	C	A	C	O	A
Sulphuric Acid (95–100%)	D	D	A		D	D	A	D	D	D	D	D			D		D	A	D	A	A	C	O	D	C	C	C	C	A
Sulphuric Acid (Spent)	D	O	A			D	A	C	C	C	A	C			B			A	A										
Sulphurous Acid	A	A	A	B	B	A	A	B	B	B	A	B	B	B	B	C	D		A	C	C	C	O	D	C	B	B	B	D
Talc Slurry	A	O	A		A	A	A	A	A	A	A	A			A														
Tallow, Molten	B	O	A		A	A	A	A	A	A	A	A			B														
Tannic Acid	A	A	A	O	A	A	O	A	A	A	A	A	A	A	B	A	A		A	C	C	A		A	A	B	A		C
Tannin	A	O	A		A	A	A	A	A	A	A	A			A														
Tar	B	O	A		A	A	A	C	C	D	D	C	A	A	A	A													
Tar Acids	A	O	A		A	A	A	C	C	D	D	C			B														
Tartaric Acid	A	A	A	O	A	A	O	A	A	A	A	A	A	A	A	A	C		A	C	C	A		A	A	C	C		C
Tennox[4]		O	A			O	A	O	O	O	O	O			O														
Tetraphosphoglucosate		O	A			A	A	A	A	A	A	A			A														
Thiamine Hydrochloride		O	A			A	A	O	O	O	O	O			B														
Thiophene		D	A			A	A	O	O	O	O	O			O														
Toluene	B	D	A		A	A	A	D	D	D	D	C	A	A	A	A	A		A	A	A			A					A
Toxaphene		O	A			A	D	O	O	O	O	O			O														
Tretolite		O	A			O	A	O	O	O	O	O			O														
Trichloroacetic Acid		O	A			A	A	O	B	C	O	O	B	C	B	B						D		D	D		D		
p-Trichloro Benzene	D	O	A			A		D	D	D	D	D			B														
Trichloroethylene (Dry)	D	O	A			A	A	D	D	D	D	C	A	A	A	A	A		A	A	A	C	O	C	C	D	D	D	C
Trichloroethylene (Moist)	D	D	A			A	A	D	D	O	D	C	B	B	A	B													
Triethanolamine	A	O	A	O	A	A	A	A	A	A	A	A			D														
Triethylamine		O	A			A	A	A	A	A	A	A	A			D													

---

[4] *BHA (butylated hydroxyanisole), Tennessee Eastman Corp.*

(cont. on p. 134)

the structure or mechanism will be subject to cold working in service. Such an area could set up a galvanic couple with a nonworked area under proper conditions.

5. Watch for statically, but highly loaded, springs which may fail when exposed to a corrosive service condition.

6. Do not adopt parts proven in one application to a completely foreign application without examining the new situation from a corrosion standpoint.

7. Avoid designs, if possible, where the stress level will be raised due to assembly conditions.

8. Avoid situations where a combined stress application may raise the equivalent stress to a critical level, i. e., overhanging shafts in gear or chain and sprocket drives, etc.

9. Be sure that gear teeth stresses are at a safe level when running in corrosive media.

The above examples are only representative of the situations which the designer must keep in mind when his equipment will or is apt to be used in a corrosive situation. The list is virtually endless.

The problem is fundamentally this: A compromise must be worked out in which the economics, public safety, reasonable service life, maintenance, appearance, operation and functional factors are properly balanced.

Direct chemical attack

This class of problems is simpler than that of members under stress in corrosive environments. The definition of chemical attacks presupposes an absence of loading or stressing of the material to any degree. It is the chemical union of the corrosive environment.

The literature is full of references to materials vs corrosive media, and the problem really becomes one of picking an economically feasible material from the list of those recommended.

If none of the recommended materials is considered economical, one approach may be found in trying to eliminate or render inactive the specific corrosion inducers.

RATING CHART FOR CORROSION RESISTANCE (cont.)

Rating **A—Excellent 0.006 ipy** **B—Good 0.016 ipy** **C—Fair 0.050 ipy** **D—Unsatisfactory** **O—No Data**	**Hard rubber**	**Methyl methacrylate**	**Teflon**	**Polyvinyl chloride**	**Nylon 101 and 31**	**Carbon/graphite**	**Ceramic (alumina)**	**Natural rubber**	**Neoprene**	**Silicone rubber**	**Buna N**	**Butyl**	**Red brass 85-5-5-5**	**Admiralty bronze**	**Ampco metal (Al bronze)**	**Nickel silver**	**Monel**	**Hastelloy D**	**Cupro-nickel (Waukesha 20)**	**Stainless Steels**									**Cast iron**
																				302	**303**	**304**	**308**	**316**	**321**	**410**	**430**	**440**	
Trisodium Phosphate		O	A		A	A	A	A	A	A	A	A			B														
Turpentine	A	A	A		A	A	A	C	B	D	D	A	A	A	A	A	A		A	A	A			A					A
Varnish	A	O	A		A	A	O	C	A	O	C	A	A	A	A	A	A		A	A	A	A		A	A	A	A		C
Vinegar	A	A	A	B	A	A	O	A	A	A	A	A	B	C	B	B	O		A	C	C	A		A	A	A	A		D
Vinyl Chloride		O	A			A	A	O	O	O	O	O			O														
Wax (Emulsion)	A	A	A		A	A	A	O	B	O	O	A			A														
Wax (Molten)	D	O	A		A	A	A	O	O	O	O	O			B									A					
Whiskey and Wines	A	A	A	A	A	A	A	A	A	A	A	A			A		A		A	A	A			A					D
Xylene	B		A		A	A	A	D	D	D	D	C			A														
Zeolite	A	O	A	A	A	A		A	A	A	A	A			O														
Zinc Acetate	A	O	A	A	A	A		A	A	A	A	A			B														
Zinc Ammonium Chloride	A	O	A		A	A		A	A	A	A	A			C														
Zinc Chloride	A	A	A	A	A	A	A	A	A	A	A	A	C	C	B	C	C		A	D	D	A		D	A		A		C
Zinc Hydrosulfite	A	O	A		A	O	A	A	A	A	A	A			C		A		A	A	A			A					
Zinc Sulfate	A	A	A	A	A	A	A	A	A	A	A	A	B	B	A	B						A		A	A		A		C
Zinc Sulfate (Acid)	A	O	A		A	A	A	A	A	A	A	A			B							A		A	A		A		

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Galvanic couples

The first rule to be remembered in coupling metals galvanically is —*don't!* This, however, is an oversimplification of the case because there are situations in which this type of coupling cannot be avoided. There are a few rules of thumb to follow when a galvanic couple is unavoidable.

1. Keep the anode area as large as possible in relation to cathode.
2. If practical, insulate the anode from the cathode.
3. Keep the two metals as close as possible to each other in the galvanic series, commensurate, of course, with proper function of the design.
4. Do not coat the anode with a protective coating, such as paint.
5. Consider the practicality of cathodic protection.

These points, with the exception of cathodic protection, have been discussed previously.

Cathode protection is the name given to the device of using a material which is more anodic than the material being protected and which will be preferentially attacked. The protecting material is known as the sacrificial anode and will have to be replenished from time to time since it is degraded in preference to the original anodic material. This system is frequently used to protect buried pipe lines, water tanks, etc.

The preceding remarks refer to the coupling of two dissimilar metals. Under these conditions, the designer knows he has a galvanic cell and can provide for it. Where the galvinc cell is the result of oxygen or metal ion concentration, nonmetallic inclusions or an active-passive situation, the designer is not forewarned. It is considerably more difficult to reduce this type of attack.

The designer must learn to anticipate situations where corrosive attack might result from a certain design configuration, and then avoid using such designs wherever possible. For instance, points in a flow stream, such as projections or depressions, where deposits could build up and give rise to a concentration type cell, should be avoided. Joints between mating parts where crevice corrosion might result, are undesirable. Lap joints in sheet metal or one part bearing against another, such as a tank in a cradle, could result in concentration cell corrosion.

It is up to the designer in the last analysis to make a study of the field in which he is engaged and determine how fundamental corrosion principles apply to the products in that field. Only then will he be able intelligently to consider corrosion as one of his design parameters.

Discussions in this paper were intended to present a brief picture of the subject of corrosion; to point out the tremendous problems of corrosion mitigation; to show how corrosion definitely is a design parameter and that it must be met on a design level; and, above all, to stimulate designers to pursue a study of corrosion and apply the principles they learn to their work. If these objectives were to be realized, it would be a big step toward the elimination of one of industry's greatest and most costly problems.

References

Corrosion, published monthly by the National Assn. of Corrosion Engineers, Houston, Texas.

Uhlig, *Corrosion Handbook*, John Wiley & Sons, New York.

Corrosion of Metals, American Society for Metals.

Speller, *Corrosion; Causes & Prevention*, McGraw-Hill Book Co., New York.

"Stress Corrosion Cracking," a symposium, American Society for Testing Materials and American Institute of Mining and Metallurgical Engineers, New York.

Deterioration of Materials, Reinhold Publishing Corp.

Henke, R. W., Notes on a System for Rating Pitting Type Corrosion, *Corrosion*, Jan., 1955.

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MATERIALS ENGINEERING FILE FACTS

MATERIALS & METHODS • NOVEMBER 1955 • NUMBER 307

Standards, Specifications and References for Metal Powders and Metal Powder Products

Cross-reference for standards, specifications and other data for metal powders and metal powder products published by the American Society for Testing Materials (ASTM), Metal Powder Association (MPA), Society of Automotive Engineers (SAE) and Federal agencies, including the military.

Title	Designation		
	MPA	ASTM	Other
Metal Powders			
Sampling Finished Lots of Metal Powders	1–45	B215–48	
Determination of Hydrogen Loss of Metal Powders	2–48		
Determination of Flow Rate of Metal Powders Precision of Above	3–45 Supplement to 3–45	B213–48	
Determination of Apparent Density of Metal Powders Precision of Above	4–45 Supplement to 4–45	B212–48	
Sieve Analysis of Granular Metal Powders	5–46[1]	B214–48[2]	
Determination of Insoluble Matter in Iron and Copper Powders Precision of Above	6–45T Supplement to 6–54T		
Determination of Iron Content of Iron Powder Precision of Above	7–54T Supplement to 7–54T		
Subsieve Analysis of Granular Metal Powders by Air Classification	12–51T	B293–54T	
Determination of Green Strength of Compacted Metal Powder Specimens	15–51T		
Aluminum Pigment; Powder and Paste, for Paint			TT-A-468a
Aluminum Powder, Flaked, Grained and Atomized (for use in ammunition)			JAN-A-289
Aluminum Powder (grained or atomized) from Secondary Metal			JAN-A-512
Aluminum Powder, Superfine			JAN-A-667
Antimony, Powdered, Technical			MIL-A-10841A
Brass Powder (for sintered parts)			MIL-B-11552
Copper, Phosphor			QQ-C-571
Copper Powder (for use in ammunition)			JAN-C-768
Iron Powder (for pyrotechnics)			MIL-I-12058
Magnesium-Aluminum Alloy, Powdered			JAN-M-454
Magnesium Powder (for use in ammunition)			JAN-M-382A
Manganese, Powdered (for use in ammunition)			JAN-M-476A

(Continued on p. 139)

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Insist On B&W Pressure Tubing

UNDER PRESSURE? TRY 4500 PSI AT 1150 F

There's a new concept in big boiler design: The Universal Pressure Steam Generator. It operates either below the critical—3206 psi—or smashes through the pressure barrier. A unit now being built has a design pressure of 5500 psi, delivers steam at 4500 psi and 1150 F. It's a "once-through" unit; put water in one end of a tube and steam comes out the other, without using a steam drum.

When B&W engineers designed this new boiler they turned to their own metallurgical and tubular products experience with alloys for pressure and temperature service to devise the tubing complex that is the heart of the unit. The chart shows the variety of analyses in sizes from 1-inch O.D. to 2½-inch O.D. and wall thicknesses from 0.10-inch to 0.55-inch.

Carbon Steel • Carbon Moly
Croloy ½ • Croloy 1
Croloy 1¼ • Croloy 2¼
Croloy 3M • Croloy 9M
Croloy 18-8

The best way to avoid operating under *personal* pressure on any job is to call for B&W Pressure Tubing. There's a grade, size, length and wall for virtually every pressure, temperature and corrosion resistance requirement. *Write for Technical Bulletin 6. MM.*

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Alliance, Ohio: Welded Carbon Steel Tubing
Milwaukee, Wis: Seamless Welding Fittings

TA-5028(P)

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MATERIALS & METHODS • NOVEMBER 1955 • NUMBER 307

Standards, Specifications and References for Metal Powders and Metal Powder Products (cont.)

Title	Designation		
	MPA	ASTM	Other
Nickel, Powder (for use in ammunition)			JAN-A-412A
Tin, Pulverized			JAN-T-458
Titanium, Powdered			MIL-T-13405
Tungsten, Powdered			MIL-T-13827
Zinc Dust (for use in pyrotechnics)			JAN-Z-365
Zinc Dust (metallic zinc powder); Dry (paint pigment)			TT-Z-291
Zirconium-Nickel Alloy Powder (for use in delay compositions)			MIL-Z-11410A
Zirconium, Powdered (for use in ammunition)			JAN-Z-399A
Metal Powders Commercially Available, Grades and Types	DS 3		
Metal Powder Bearings			
Metal Powder Sintered Bearings (oil-impregnated) Preferred Dimensional Specifications	14-51T		
Metal Powder Sintered Bearings (oil-impregnated)	16-52T	B202-55T[3]	
Sintered Metal Powder Parts (bearings and structural parts)			SAE
Bearings, Sintered, Metal Powder (oil-impregnated) Aircraft			MIL-B-5687A
Metal Powder, Structural Parts			
Acceptance Tests on Structural Parts Made from Metal Powders	8-50		
Tension Test Specimens for Pressed and Sintered Metal Powders	10-50		
Determination of Bending Strength, Green Density, Hardness and Shrinkage of Compacted Sintered Metal Powder Specimens	13-51T		
Sintered Metal Powder Parts (bearings and structural parts)			SAE
Copper Infiltrated Iron Parts		B303-55T	
Sintered Metal Powder Structural Parts		B222-52	
Sintered Metal Powder Structural Parts from Bronze		B255-54T	
Sintered Metal Powder Structural Parts from Brass		B282-53T	
Brass, Sintered, Structural Parts			MIL-B-12128A
Metal Powder, Ferrous, Sintered; Structural Parts			MIL-M-13749
Electronic Cores			
Electronic Core Materials and Core Manufacturers' Designations	DS 1		

(Continued on p. 141)

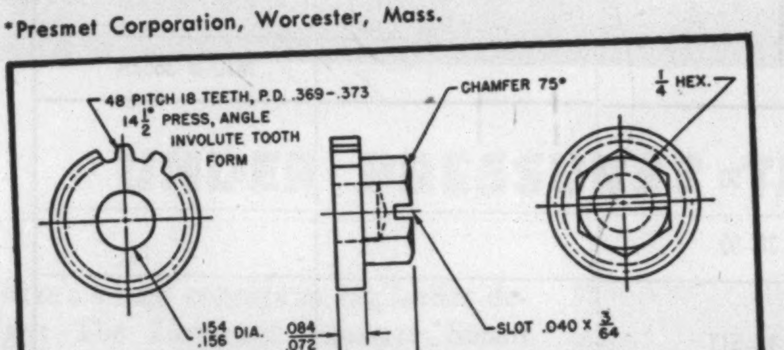
FOXBORO and RAPIDPRINT

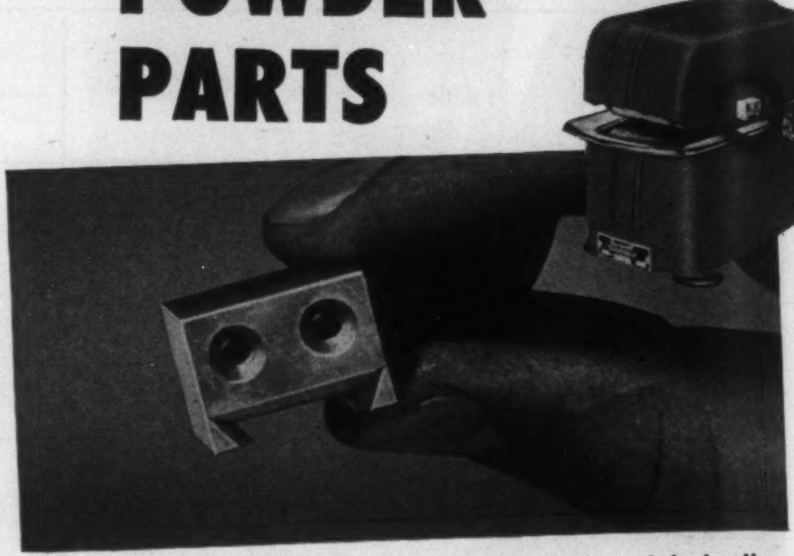
each save 68¢ per unit

with BRASS and NICKEL SILVER POWDER PARTS

When production requirements increased for the Model 53 Consotrol Recorder, The Foxboro Company switched to a brass powder part for this pinion gear. The gear was formerly machined from pinion stock, involving (1) turning of the stock to provide the head, (2) drilling the hole, (3) cutting off, (4) milling the screw driver slot, and (5) wire brushing to remove burrs. *Total cost was 74 cents per gear!* As a brass sintering the gear is now pressed to finished shape and size in one operation* and *the cost is 5.8 cents per gear!* In addition to saving more than 68 cents, production from brass powder permits the addition of flats to the pinion heads.

*Presmet Corporation, Worcester, Mass.

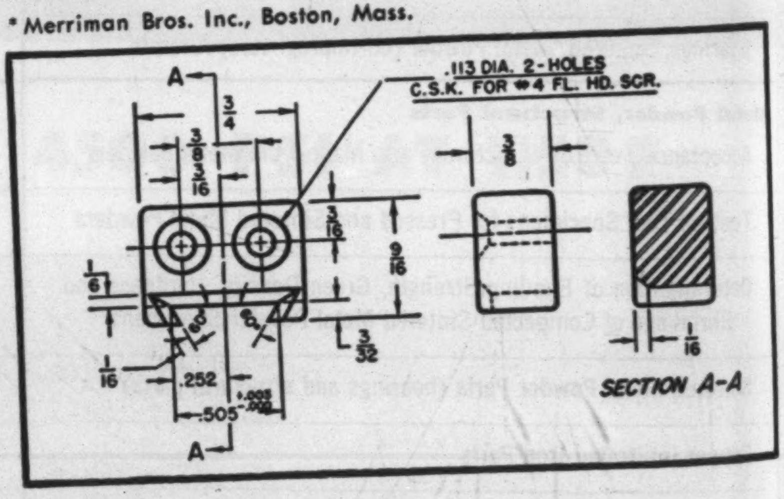

48 PITCH 18 TEETH, P.D. .369-.373
14 1/2° PRESS, ANGLE INVOLUTE TOOTH FORM
CHAMFER 75°
1/4 HEX.
.154 .156 DIA.
.084 .072
7/32
1/8 DEEP
CONCENTRIC WITH PITCH DIAMETER WITHIN .006 T.I.R.
SLOT .040 × 3/64



This odd-shaped part is pressed from nickel silver powder* and needs merely to be buffed to produce a high lustre prior to assembly on the side of the Rapidprint time recorder. Formerly shaped from cold rolled steel, involving milling, drilling, reaming, counter sinking and plating operations, *the nickel silver sintering represents a saving of 68 cents per piece!*

The nickel silver powder part is a guide block used for inserting a removable engraved die plate into its proper position on the Rapidprint time recording machine.

* Merriman Bros. Inc., Boston, Mass.


A
3/4
3/8
3/16
.113 DIA. 2-HOLES
C.S.K. FOR #4 FL. HD. SCR.
3/8
3/16
9/16
1/6
60°
60°
3/32
1/16
.252
.505 +.005 -.000
A
1/16
SECTION A-A

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POWDER PARTS

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For detailed information on the design, properties, production and application of brass and other nonferrous powder parts you should have a copy of our manual. It will give you 24 case histories of brass and nickel silver powder structural parts to assist in evaluating this means of production in terms of *your* particular needs.

THE NEW JERSEY ZINC COMPANY

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HORSE HEAD PRODUCTS

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MATERIALS & METHODS • NOVEMBER 1955 • NUMBER 307

Standards, Specifications and References for Metal Powders and Metal Powder Products (cont.)

Title	Designation		
	MPA	ASTM	Other
Electronic Iron Core Preferred Dimensional Specifications	11-55T		
Electronic Characteristics (Relative) of Some Basic Electronic Materials	DS 2		
Acceptance Standards for Electronic Cores	17-54T		
Preferred Dimension Specification for Ferrite Television Deflection Yoke Core Sections	18-55T		
Electrical Contacts			
Brushes; Electrical Contact; and Carbon Plates, Electrical Contact Brush			MIL-B-3743
Others			
Terms Used in Powder Metallurgy	9-50	B243-49T	
Evaluating Micro-Structure of Apparent Porosity in Cemented Carbides		B276-52T	
Hardness Testing of Cemented Carbides		B295-54T	
Tungsten Carbide, Crystalline			MIL-T-13366

[1] *Brass, bronze or stainless steel cloth; rotary motion of 285 ± 6 RPM; tapping action 150 per min ± 3; tables use 250 mesh, 50 g. sample if apparent density less than 1.50 g/cc.*

[2] *Bronze cloth; rotary motion of 140–160 RPM; tapping action 1 per revolution; tables use 230 mesh, 50 g. sample if apparent density less than 1.50 g/cc.*

[3] *Contains additional explanatory notes and tables.*

Where to Obtain Above Standards and Specifications

MPA, DS – Metal Powder Association, 420 Lexington Ave., New York 17, N. Y. (DD is an MPA Data Sheet and not a standard or specification).

ASTM – American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

SAE – Society for Automotive Engineers, 29 West 39th St., New York 18, N. Y.

JAN – Joint Army-Navy Spec., Commanding Officer, U. S. Naval Supply Depot, Scotia 2, N. Y.

TT, QQ – Federal Spec., General Service Center, GSA Region 3, 7th & D Sts., S.W., Washington 25, D. C., or local GSA Region.

MIL – Military Spec., Dept. of the Army, New York Ordnance District, 180 Varick St., New York 14, N. Y., Att: Administrative Service Div., or local Procurement District.

New York 14, N. Y., Att: Drawings & Spec. Section, or local Ordnance District.

Exceptions: MIL-I-12058, MIL-A-10841 A, MIL-T-13405 – New York Chemical Procurement District, U. S. Army, 180 Varick St., New York 14, N. Y., Att: Administrative Service Div., or local Procurement District.

MIL-B-3743 – Corps of Engineers, U. S. Army, N. Y. District, 80 Lafayette St., New York 13, N. Y., or local Ordnance District Office.

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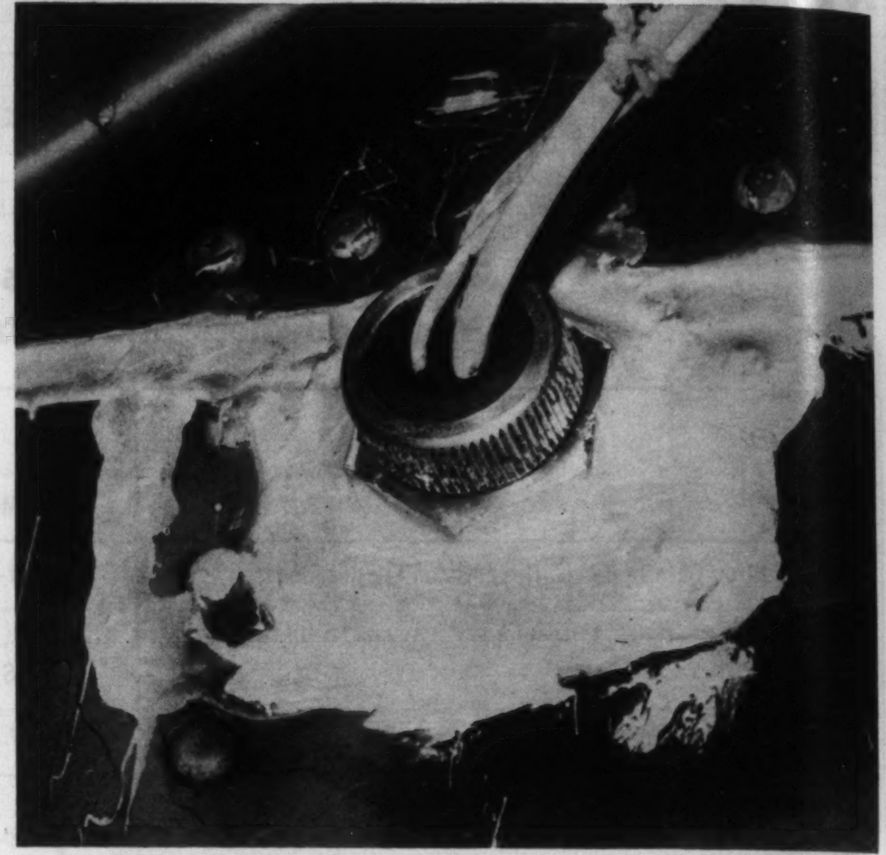
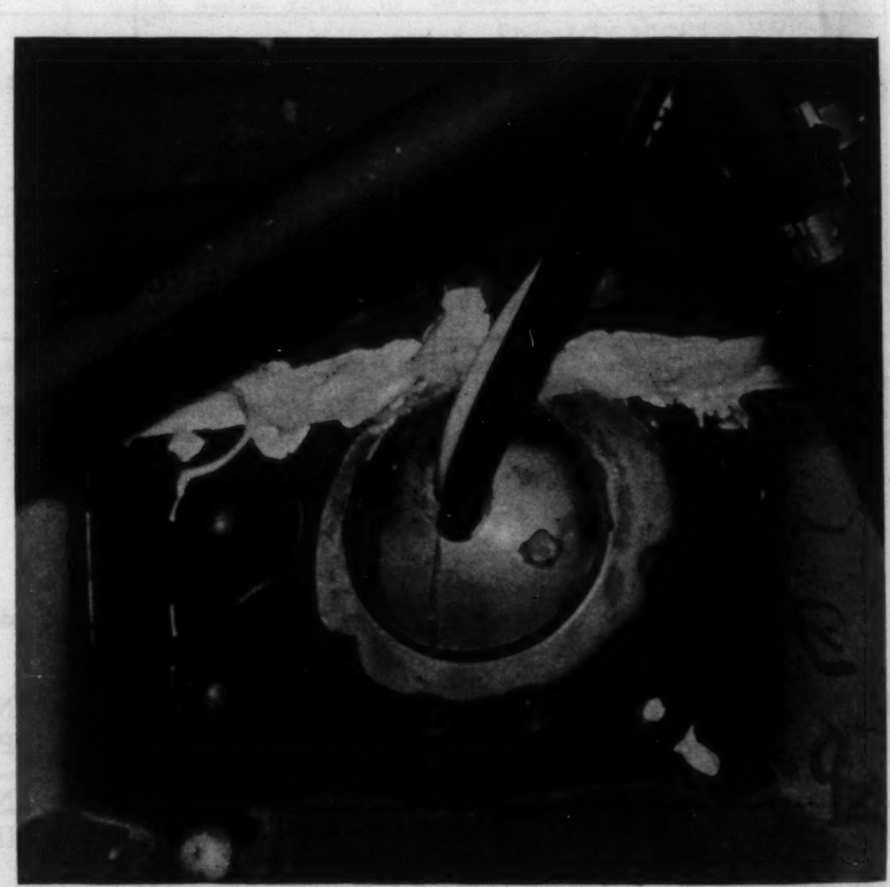
Before ➤



Standard aluminum connectors in former method of passing wire bundles through pressure areas.

After ➤

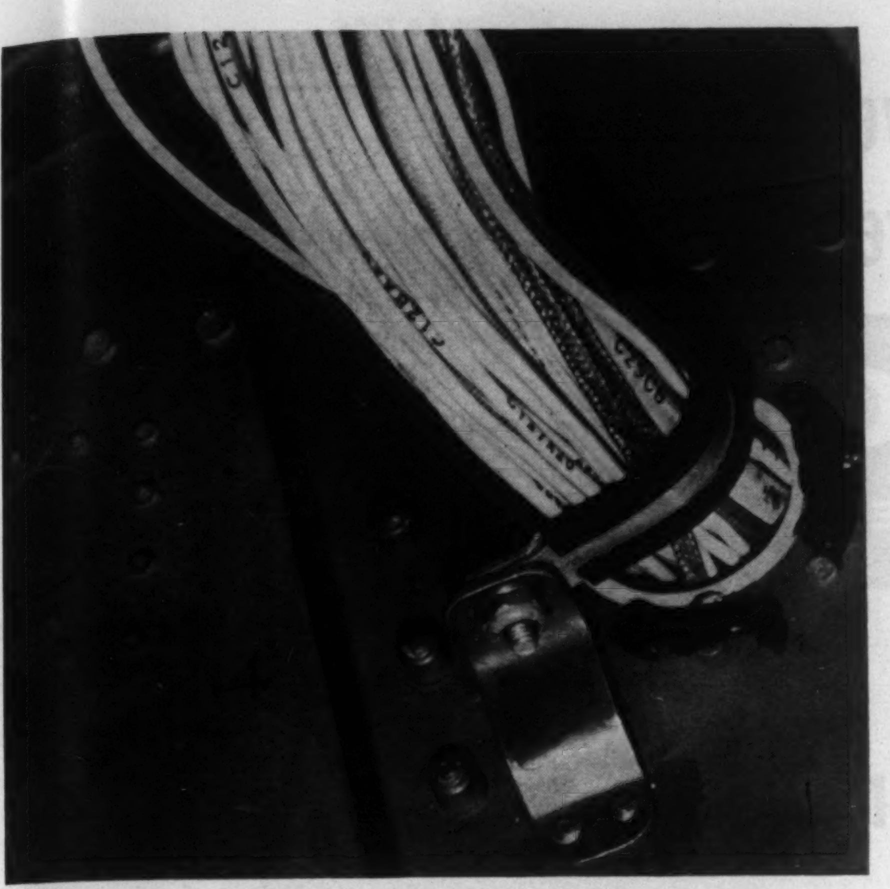


New rubber seals replace connectors in same area with the new method of wire bundle entry into pressure areas.

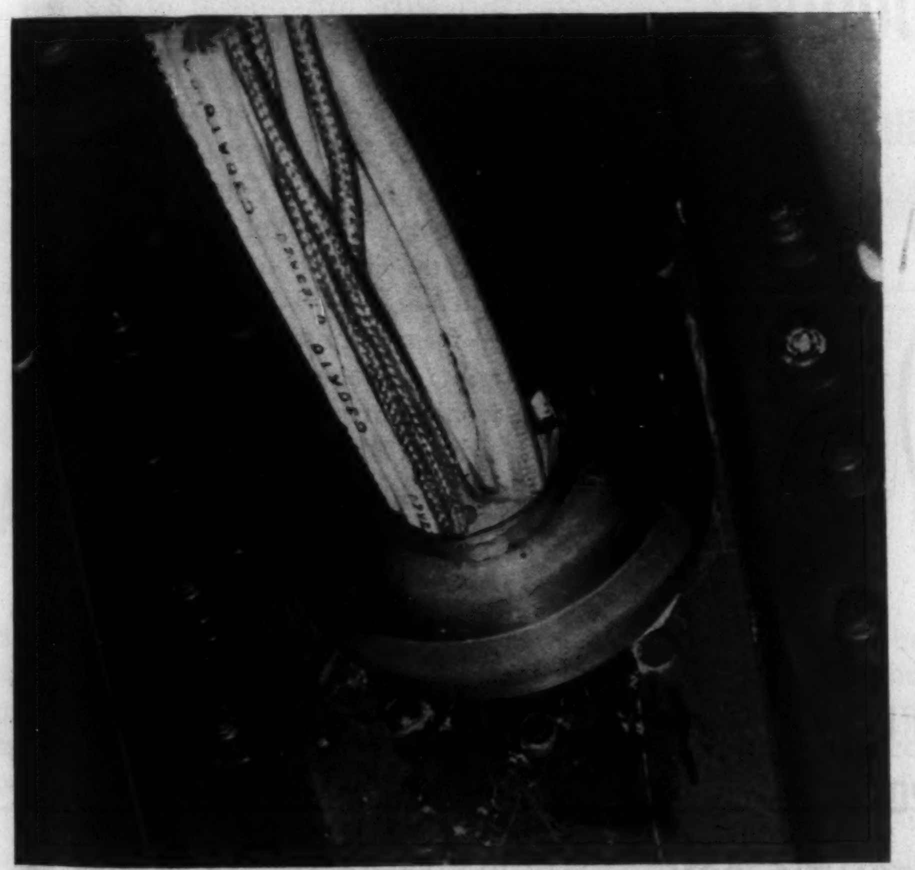
Plastics-Rubber Pressure Seals

Combination of cellulose acetate butyrate molds and polysulfide liquid polymer replaces cumbersome aluminum receptacle.

by E. N. Gomberg, *Douglas Aircraft Co., Inc.*



Plastics chicken rings support the wire bundle and help prevent movement in flight with old seals.



Same area as above. The new seal eliminates the chicken rings. Shown here is the mold ready to receive Thiokol sealant.

Cut Weight and Reduce Costs

■ A new improved method of pressure sealing wire bundles passing through bulkheads achieves a weight saving of over 90% and significantly reduces the cost of labor and material. Although developed originally for aircraft, the sealing technique can be adopted for sealing conduit, cable and hydraulic lines passing into or through pressurized areas in other structures or products.

The standard method of sealing the bundles in crowded areas on

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PLASTICS-RUBBER PRESSURE SEALS

continued from p. 143

the Douglas F4D Skyray was causing engineering problems. A standard aluminum plug-in type of receptacle was used, but it was too heavy and cumbersome for efficient installation. Preparation involved the stripping, tinning and soldering of as many as 48 wire ends to the two mating connector halves.

To solve the problem, the Methods Development Group at the Torrance facility of Douglas El Segundo Division proceeded to develop a light, compact receptacle that would meet these basic requirements:

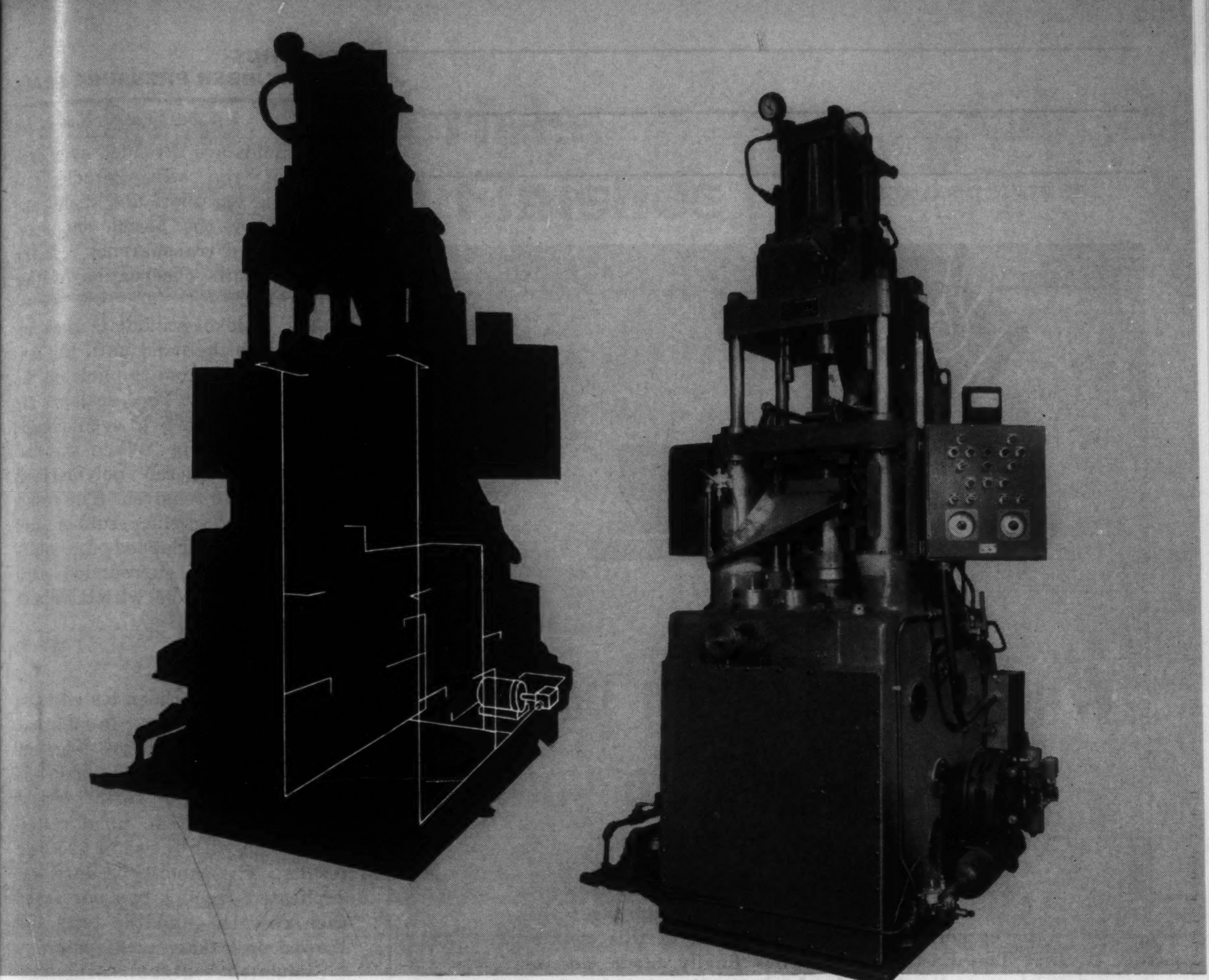
1. Individual wires must be removable from the bundle without destroying the integrity of the seal.
2. The addition of wires to the bundle must not disturb the seal's integrity.
3. The seal must withstand a pressure differential of 2.2 psig. It must also, however, withstand emergency pressure changes up to 30 psig for periods up to 30 min.

The development centered on the principle of a cold setting, nonadhesive Thiokol material (polysulfide liquid polymer) to form the seal. A hollow plastics mold to form a hemisphere, pierced and split to accept the wire bundle would form a mold cavity on each side of the bulkhead for sealant.

New seals

The material selected for the hemispherical molds is cellulose acetate butyrate compounded to specific requirements for clarity, shore hardness and viscosity at the pour point. A typical mold is cast with permanent magnets opposed to each other cast in the mold. When the hemispheres are split, the halves are self-aligning and magnetically attracted. The mold has a 1¼-in. i.d. and a 2-in. o.d. This mold is pierced at opposite sides to receive a 24-wire bundle. A smaller hole is made at the leading edge of the surface for the injection of the sealing compound.

Installation begins when the wire bundle is passed through a bulkhead hole and Thiokol material is injected between the wires with a pressure gun. The



Model L

AUTOMATIC LUBRICATION protects new Baldwin powdered metal presses

Baldwin Model "L" and "C" powdered metal presses are just what you need for highest-quality and lowest-cost production. That's true because these new 50 and 100 ton presses are the first designed specifically for compacting metal powders.

A big reason why you'll get such low cost production is their automatic lubrication. In both presses a gear type oil pump, independently driven by a fractional horsepower motor, automatically lubricates all moving parts continuously. It forces filtered oil through a drilled crankshaft to the crank and connecting rod bearings. It pressure lubricates all other bearings subject to load.

Baldwin Model "L" and "C" presses are designed so that all moving parts are completely enclosed and sealed. Abrasive powder and dirt can't get into the bearings. These presses automatically fail to operate unless there is oil pressure in the lubricating system. An easily serviced oil filter provides further protection.

No other powdered metal presses have been designed just to meet your end product's needs. That's why Baldwin's new presses are your best buy. Only they can give you such uniform compacts and so little press maintenance because they both have automatic lubrication, hydraulic heads, shuttle type feeders, sealed mechanism, simple fill adjustments and variable cycling.

For more details about "L" and "C" please write to our Dept. 3823, Baldwin-Lima-Hamilton Corporation, Philadelphia 42, Pa.

EDDYSTONE DIVISION

BALDWIN-LIMA-HAMILTON

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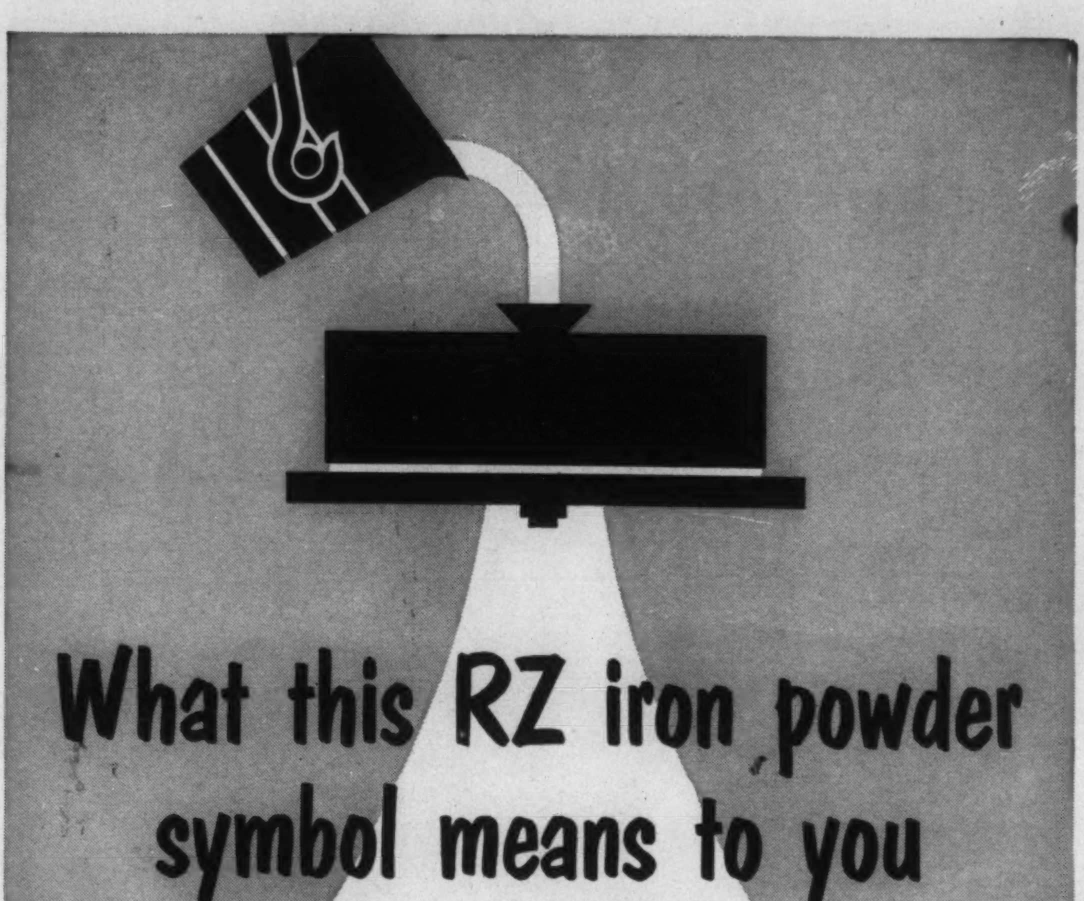

What this RZ iron powder symbol means to you

Easton's RZ atomization process symbolized here is giving users quality and cost advantages they never guessed could be obtained in this country.

The Easton process has finally made possible the production of a high-quality powder from plentiful domestic mild steel scrap.

Cost-saving without sacrifice in quality is further implemented because the process permits annealing *without* the use of expensive reducing gas.

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RZ IRON POWDER FOR EVERY REQUIREMENT

For more information, turn to Reader Service Card, Circle No. 515

continued from p. 144

half molds are threaded over each end of the wire bundle and brought together and held and aligned by the permanent magnets. The transparency of the mold permits observation of this alignment.

The Thiokol sealant is then injected into the mold until the material exudes from the hole on the opposite side. The sealant air cures in 12 hr or will oven cure at 135 F in 35 min. When the material is completely polymerized, the molds are removed. The result is a molded in-place rubber seal which has overlapped the bulkhead hole and surrounded each wire of the bundle with a rubber sleeve 1-in. long.

Seals meet tests

The seals have been tested to 30 psig without leakage. In addition, one wire was pulled free from the initial adhesion of the bond and moved back and forth several times. The system, upon resealing, tested with the same excellent results. The same procedure was duplicated freeing two wires and then resealed, and the tests still showed no leakage at 30 psig.

Simulated flight conditions showed the seal would not move in flight even under a 2-hr test at varying frequencies of 150 to 300 cycles a sec at 5 G's amplitude. Tested for continuity it was acceptable at 400 v.

These tests and an examination of the wire and its insulation after tests established that both the plastics "chicken rings" and aluminum clips normally used on the hole could be eliminated.

There were further advantages:

The pressure-proof seal may be applied at any time during assembly of the airplane. A service kit makes it possible to apply the seals in the new field.

The weight of the new seal installed is only 1-2/3 oz. The aluminum connector that it displaces weighs 1 lb 2 oz.

The elimination of a number of operations and the material savings brought the cost of the new method to only 1/70 of the method formerly used.

New Materials, Parts and Finishes | and related equipment

Non-Tracking Organic Insulation

Tracking:
What is it?
Why is it important?

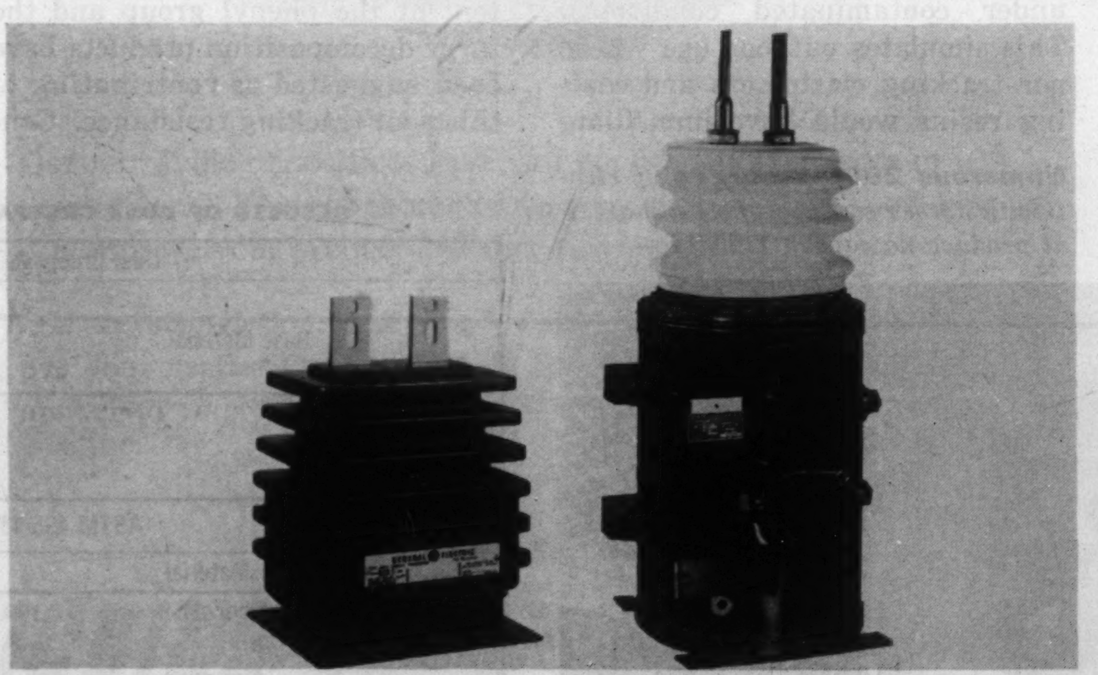
Carbon tracking of insulation results from exposure to electric arcs. Electric arcs may be caused by simply opening a circuit, or by voltage surges due to lightning, or by leakage current creeping across the surface of high voltage insulators when they become dirty. The latter is most common outdoors where insulators can become coated with dust, soot and salt deposits. In damp weather, these deposits become conducting and leakage currents flow along the surface of the insulator. Various areas on the insulation will be heated sufficiently by this leakage current to dry out and become once again a non-conductor. This interference in the conductance of the surface causes arcs to jump across the dry spot.

The sparks, which may cause temperatures as high as 3000 to 5000 F, break down the organic material, causing the formation of conductive free carbon on the insulation surface. This phenomenon has prevented widespread use of organic materials as high voltage insulation outdoors. More expensive porcelain is used instead. Though porcelain will not develop conducting carbon tracks under arcing conditions, if sparking is severe enough, porcelain will crack as a result of thermal shock.

■ Smaller, lighter electrical components such as transformers are seen as the direct result of the development of Hy-Bute/60, a modified butyl rubber incorporating a chemical mechanism which prevents formation of free carbon tracks during arcing. In effect, this means a non-tracking organic insulation has been developed. The non-tracking characteristic is obtained by making certain additions to the formulation during compounding, and experimental work has indicated that these additions can be made to other rubbers and organic plastics with similar results. An accompanying table indicates the degree of improvement in life effected for various types of materials as measured by dust creepage tests and arc resistance tests.

The material was developed by the Measurements Lab of *General Electric's Instruments Div.*, Lynn, Mass. First application of Hy-Bute/60 will be in encapsulating 15,000 v outdoor dry-type transformers. As well as its unique non-tracking characteristic, Hy-Bute/60 retains the outstanding electrical, physical and chemical properties of conventional butyl, such as resistance to ozone and corona, tearing and abrasion, acids and alkalies, as well as high dielectric strength and heat aging properties. The new material is also said to be superior to conventional butyl with respect to thermal conductivity and is self-extinguishing by ASTM-D635-33 flammability test.

(Continued on p. 150)



Weight and size *of a 15-kv outdoor transformer are almost cut in half by use of new insulation. New model at left weighs 70 lb and stands 16-in.; old type at right weighs 135 lb and stands 30 in.*

New Materials, Parts and Finishes | and related equipment

(Continued from p. 149)

Internal oxidation mechanism

The component which provides the non-tracking characteristic is a material which can be physically interspersed throughout the bulk of the basic organic material. It is added during the compounding of fillers, plasticizers, etc., with the base resin. High arc temperatures due to electrical discharge close to this compounded material are believed to break down organic components of the insulating material and simultaneously trigger an oxidation reaction forming volatile hydrocarbons and gaseous oxides of carbon. Since this prevents the formation of free carbon, no conducting track is formed, and the only effect is a very slow general erosion. Effects of this erosion in shortening life of electrical equipment can be counterbalanced by increasing thickness of the organic insulation.

Improvements in the material were measured at G-E by two general classes of tracking tests. In the first class of test, resistance to surface creepage damage by localized sparking is measured under contaminated conditions. This simulates outdoor use where non-tracking elastomers and casting resins would have immediate application. The second class of test measures resistance to an arc drawn between two electrodes on the surface of a clean material.

Experimental work is still being carried out to determine the effect of the internal oxidation mechanism on internal ionization. When insulating materials are subjected to high voltage stress, ionization will take place if internal voids are present in critical areas. Severe internal ionization may lead to rapid dielectric failure. The internal oxidation mechanism might be expected to retard internal ionization and carbonization. Limited data presently available on butyl rubber confirm the existence of this effect.

Other materials

Application of the internal oxidation mechanism to other electrical grade plastics is quite promising. Experimental work has been done with epoxide resins, neoprene, melamines, phenolics and several others. Phenolics are of primary interest due to their wide use but notoriously poor arc-tracking resistance. High carbon content of the phenyl group and the tarry decomposition products have been suggested as contributing to this poor tracking resistance. Conventional wood-flour-filled phenolics have an arc resistance of 2 to 5 sec, while conventional filled urea formaldehyde and melamine formaldehyde, which are normally felt to have good arc resistance, are in the range of 125 sec. With the internal oxidation mechanism, arc resistance of phenolics is increased from the previous 2 to 5 sec to values of 180 to 190 sec as measured by ASTM 495-48T arc-resistance test.

Applications

As mentioned earlier, immediate application of Hy-Bute/60 will be in pressure molding a 15 kv transformer in the material. Prior to development of the new material, the size of outdoor dry-type transformers was somewhat limited due to the insulation arc tracking problem. In the past, industry has relied mainly on liquid-filled transformers for sizes much above 15 or 20 kv. By using molded butyl insulated transformers the hazards and mess involved in oil and associated seals, gaskets and presure reliefs would be eliminated.

References

Non-Tracking Organic Insulations, R. S. Norman, R. A. Pfuntner, A. A. Kessel, AIEE Technical Paper, presented before Fall General Meeting in Chicago, Oct. 3-7, 1955.

The Application of a New Non-Tracking Butyl To High Voltage Instrument Transformers, R. A. Pfuntner, R. S. Norman, B. W. Wilterdink, AIEE Technical Paper, presented before Fall General Meeting in Chicago, Oct. 3-7, 1955.

(More New Materials on p. 152)

Numerous 2000 v surges *of electricity across surface of new material produce no carbon tracking.*

DANGER
HIGH VOLTAGE

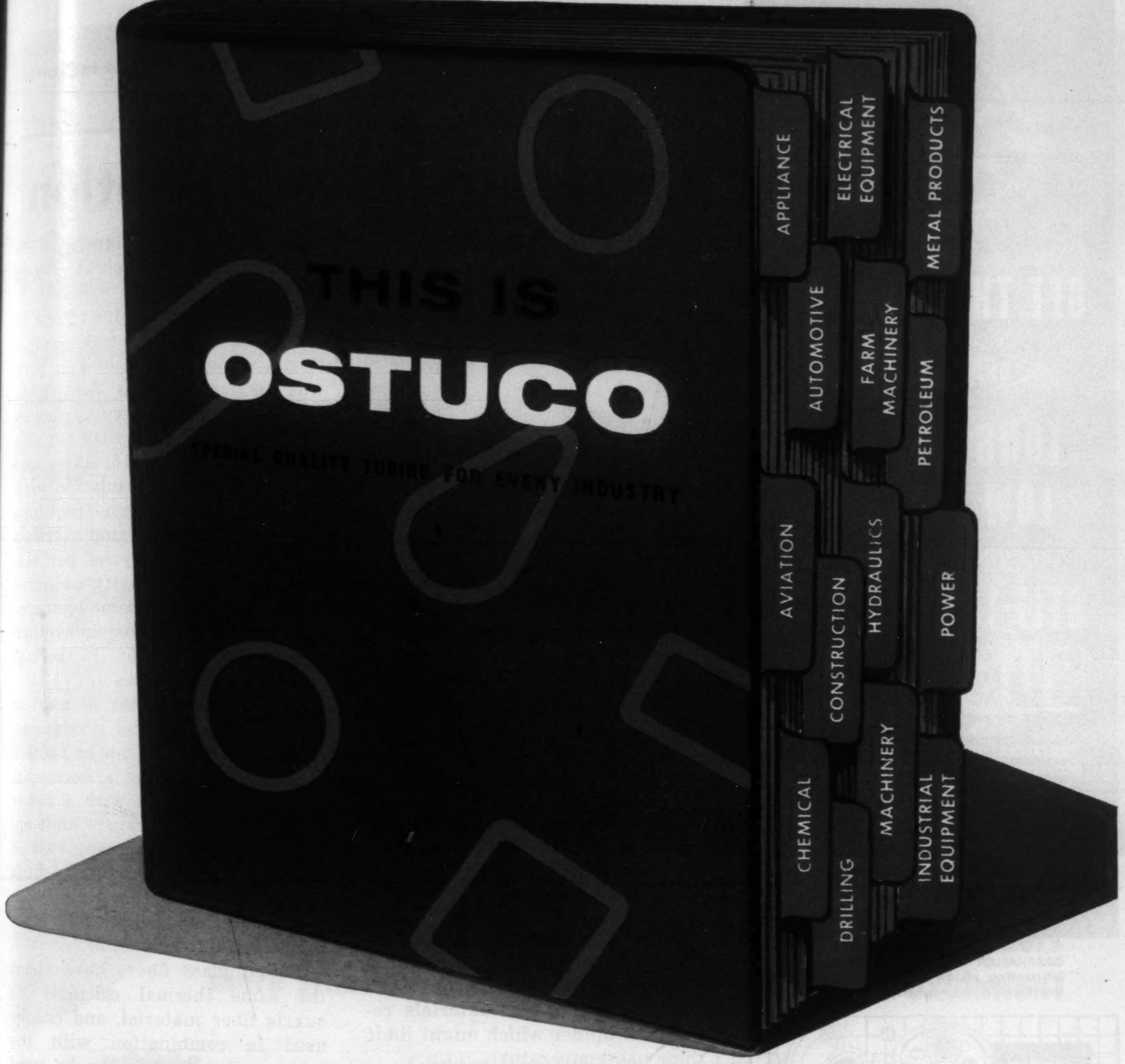
RESULTS OF DUST CREEPAGE AND ARC RESISTANCE TESTS

Dust Creepage Test On 75-Mil Samples

Base Material	Hours to Failure	
	Conventional Filled	Utilizing Internal Oxidation Mechanism
Butyl Rubber	2.0	400
Epoxide Resin	0.5–40	400
Neoprene	1.0	31

ASTM 495-48T Arc Resistance Test

Base Material	Average Time in Sec
Phenolic	4
Urea	125
Melamine	125
Vulcanized Fibre	125
Phenolic Utilizing Internal Mechanism	185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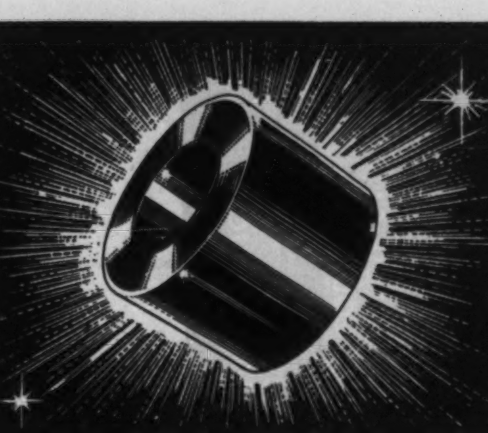

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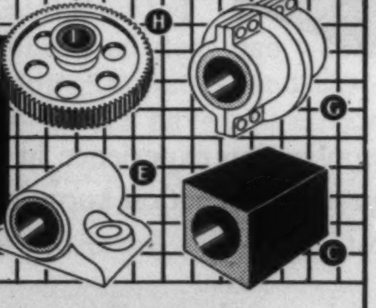

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New Materials, Parts and Finishes | and related equipment

Inorganic Fiber Insulation

***Glass or quartz fibers** such as these have been woven into flexible sheets of insulation.*

Two high temperature insulating materials consisting of inorganic fibers felted into a flexible sheet material have recently been marketed: 1) E-Felt, consisting of felted fibers of borosilicate glass, is intended for insulation use at temperatures up to about 1000 F and 2) Q-Felt, consisting of felted fibers of fine quartz, is intended for use at temperatures up to about 2500 F. Both types of fibers are also available as bulk fibers. Developed by *L.O.F. Glass Fibers Co.*, 1810 Madison Ave., Toledo 1, Ohio, the materials require no binder which might limit their use temperature.

Physical properties

Fiber diameter averages about 0.00003 in., or about ¾ micron. Standard felt is made to a nominal thickness of 3/16 in., a nominal density of 3 lb per cu ft, and 71 in. long by 34 in. wide. Color varies from light tan to reddish brown. An accompanying table shows shrinkage and loss of weight of the material when exposed to temperatures throughout its working range. Resistance to flow of air through standard felt blankets indicates resistance to heat transfer by convection through the insulation. Felt of standard thickness and density produced a resistance of 3 in. of water at a flow rate of 30 ft per min. An accompanying table also indicates compressibility and recovery of the felt at various compression loads.

In a test to determine effects of vibration upon thermal conductivity, a short length of 4-in. pipe was insulated with a 1-in. thickness of felt, and thermal conductivity was measured with hot side temperatures of 1116, 1240, and 1520 F. Pipe and insulation were then placed in a high frequency vibration apparatus and vibrated for 48 hr at 100 cycles per sec. Subsequent conductivity measurements taken at the same temperatures as before showed an average increase of about 1.5% in thermal conductivity.

The quartz felt may be used as a composite with other insulations, especially where it can be applied to the hot side, and a lower-cost insulating material with a lower top working temperature limit applied over it. In this way cost of insulation can be reduced. Bulk fibers may be used loose in a confined space, or used with a sheeting material to hold them together.

Felted glass fibers have about the same thermal efficiency as quartz fiber material, and can be used in combination with the quartz. Quartz felt can be used

CHARACTERISTICS OF STANDARD FELTED SHEET

Shrinkage and Weight Loss at Temperature		
Temp, F	Linear Shrinkage, %	Loss of Weight, %
1000	1.25	5.48
1200	2.50	4.98
1600	2.50	9.99
1800	3.75	9.50
2000	5.00	9.88
2500	5.83	9.93

Compressibility and Recovery			
Load, psf	Comp under Load, %	Resid Comp after unloading, %	Resid Comp 16 hr after unloading, %
5	5.0	2.0	1.0
10	9.0	4.0	1.5
25	18.0	8.0	3.0
50	30.5	11.0	5.0
100	43.0	15.0	6.0

The striking difference in color shows comparative resistance to oxidation, proves superiority of RESISTOX Metal Powder (left) when exposed same length of time as ordinary powder.

Resistox Process gives Glidden Metal Powders more stability through greater resistance to oxidation!

Glidden Resistox Metal Powders offer you distinct storage and production advantages over ordinary metal powders because they resist oxidation from 5 to 10 times longer!

This exclusive Resistox Process permits storage over long periods of time without fear of oxidation, thus eliminating production and product-quality problems.

Glidden Resistox Metal Powders meet every requirement for uniformity, purity, consistency, strength. There is less material waste and die wear. They permit faster production of precision parts with greatly improved finish, appearance and performance characteristics.

Let us supply you with more complete information on these Glidden products: Resistox Copper and Lead Powders, Cuprous Oxide, Cupric Oxide and Cubond (Copper Brazing Paste). There's no obligation.

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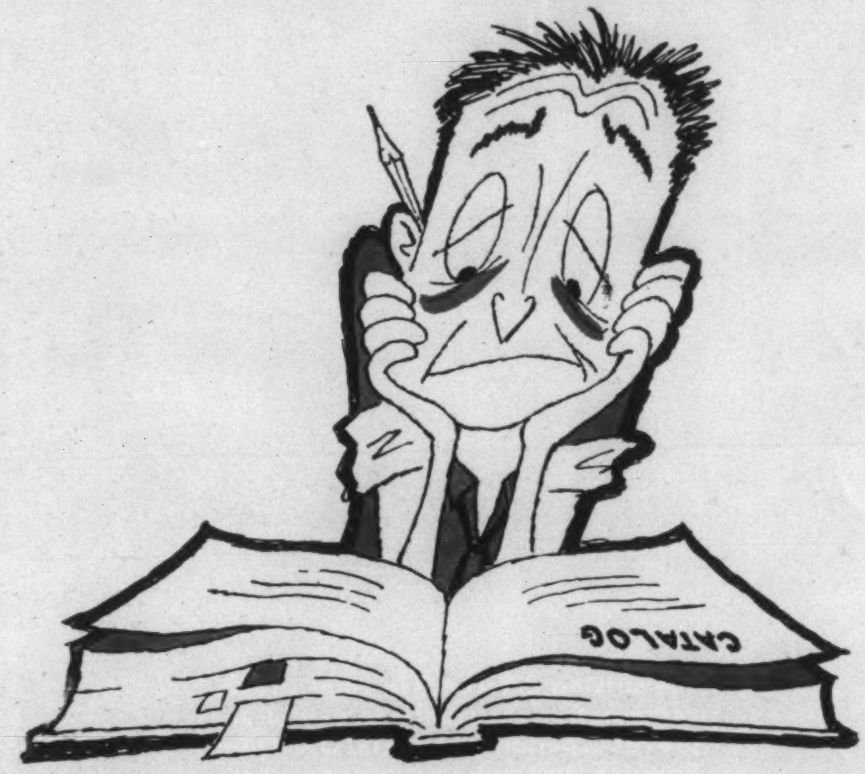

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on the hot side and glass felt, with its lower top working limit can be applied over it to obtain required over-all insulation. Thermal conductivity should be calculated as if quartz felt were used throughout the entire thickness. Borosilicate glass fibers have a softening point of about 1500 F, therefore they are not used for service above 1000 F, and L.O.F. recommends 850 F as the top working temperature to provide a generous safety factor.

Applications

Since the material is supplied as a flexible felted sheet, it can be applied over irregular objects as well as around piping. Its light weight suggests its use for applications where portability is a consideration, or where maximum thermal insulation must be obtained with minimum thickness. Other applications for which the material would provide advantages, in addition to the high temperature use already mentioned, are those in which low heat capacity in the insulation, high heat diffusivity, frequent cycling from low to high temperatures, and necessity for rapid heating to a high temperature are conditions of service.

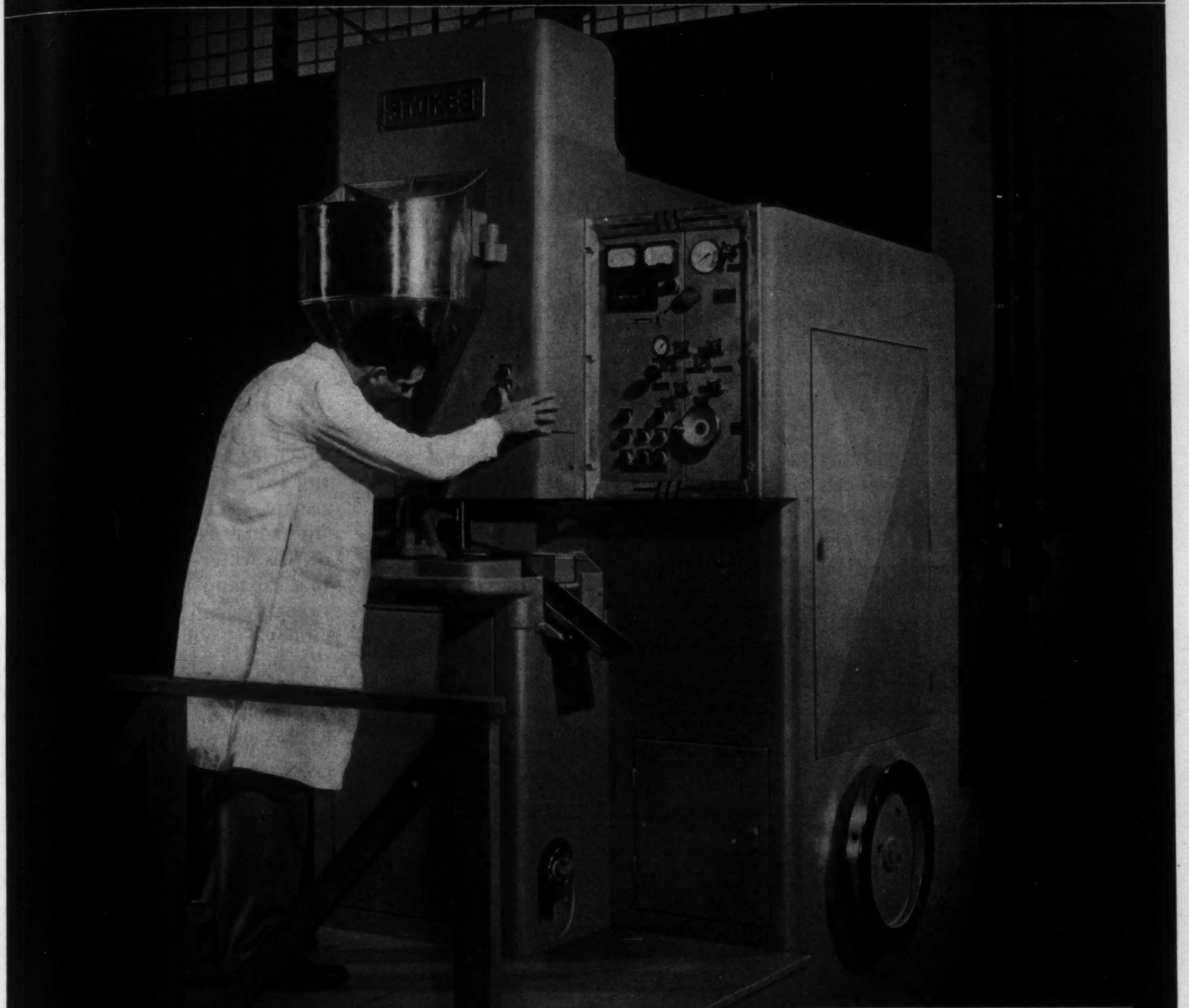
Glass paper

In addition to its use as felted sheet or bulk insulation, glass fibers may be made into glass paper on a standard Fourdrinier papermaking machine. A run with glass fibers made into a slurry with water and processed on a Fourdrinier with a 70-mesh wire, 33 ft long produced a glass paper 0.0075 in. thick with a tensile strength of 177 psi. These glass papers are used in electrical insulation, as filtering media, and for other uses outside the thermal insulating field.

(For further information watch for article on inorganic papers, MATERIALS & METHODS, December issue)

(More New Materials on p. 156)

NEW versatile STOKES powder metal press



A new 50-ton multiple-motion press offers increased economy to powder metal molders

The pieces shown are typical of parts for which the Model 640 press is particularly well suited. Difficult parts like these and pieces with double hubs, multiple levels and thin flanges all can now be made economically on the Stokes Model 640 press.

Here is a powder metal press so new, so radically different from anything in the field today that it presents entirely new possibilities for efficient industrial compacting. With its simplified tooling and fast operation, the 640 press outdates all other designs; makes possible the application of powder metal to the production of parts for which the process has never before been considered economical.

The Stokes Model 640 is a completely new design, based on an intimate knowledge of the industry's requirements. It represents the latest achievement in Stokes 35-year experience in the design and manufacture of presses specifically for powder metallurgy.

For example, the 640 press is the first to give full, *50-ton simultaneous breakaway* on multiple lower punches, important in successful ejection of complex parts; *centralized controls,* for easy, fast set-up and operation; *independent adjustments* of all press actions while the machine is running; *direct-reading handwheel calibrations,* that eliminate guess-work on settings, permit exact records for each piece produced.

If you are now compacting powdered metals or are investigating how this economical process can be applied to your production, you should know about the many exclusive features of the Stokes Model 640 press. Write for Bulletin 670.

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ALLOY *and* SPECIALTY POWDERS

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ELECTROLYTIC IRON POWDERS

Characteristics of Hydrogen Reduced Iron Powders:

- Dependable uniformity of chemical and physical properties
- Offer good physicals on straight iron parts
- Provide unusual dimensional stability with copper
- Combine readily and uniformly with graphite
- Readily employed for infiltration with copper

FOR PRICES AND TECHNICAL DATA WRITE:

PYRON CORPORATION, Box E, LaSalle Station, Niagara Falls, N. Y.

GAR-FORMING

for extreme accuracy and exact duplication

complex internal shapes made "INSIDE OUT"

This unique electroforming process produces precision, internally-shaped parts, such as this microwave coupler, with internal accuracies and configurations unobtainable or economically prohibitive with any other method.

The intricate interior is formed from the inside out, and may include machined parts that are grown in place during electroforming to produce an integral assembly of unusual accuracy, rigidity, and lightness.

Machined flanges are also grown in exact position to eliminate heat distortion associated with fabrication methods.

Offering new concepts in the design of intricate precision parts, Gar-forming provides highest accuracy in any quantities at surprisingly low costs.

Send today for full information GAR PRECISION PARTS, INC.
1 Ludlow Street, Stamford, Conn.

For more information, turn to Reader Service Card, Circle No. 406

New Materials, Parts, Finishes

Varnish for Printed Circuits

A varnish designed especially as a protective insulating coating for modular assemblies, printed circuits and printed circuit components has been developed by Schenectady Varnish Co., and is being marketed by *The Insl-X-Sales Co.*, 26 Rittenhouse Pl., Ardmore, Pa. More flexible than conventional coatings, Schenectady No. 642 varnish can be baked or air-dried to a tough, resilient coating that seals laminates and component leads against arc-producing moisture. A 2.5 mil coating of this water-white varnish is said to withstand 1250 v after 72 hour exposure to 100% relative humidity. It will not support tracking, nor will it char. It is said to be free from aging characteristics or discoloring and may be thinned with Xylol or its equivalent.

Bonded Staple Sliver

A low cost staple glass fiber product called Bonded Staple Sliver, is now commercially available from *Owens-Corning Fiberglas Corp.*, 598 Madison Ave., New York. It retains the lofty bulk inherent in staple sliver, but has sufficient strength to weave and braid. Cloths woven from the product will have applications in the electrical and other industries wherever bulk is desirable.

The material consists of glass fibers varying in length from 8 to 15 in. bonded with a polymerized oil and produced in a range of thicknesses. When not subjected to compression, bulk is about 50% greater than that of equivalent weight of Fiberglas staple yarn and more than 100% greater than that of Fiberglas continuous filament yarn. A bonded staple sliver occupying the same space as any given Fiberglas continuous filament yarn will have a yield of more than twice the number of

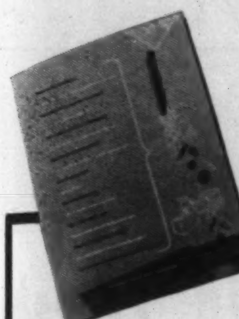
For more information, turn to Reader Service Card, Circle No. 502

POWDER METALLURGY PARTS *ECONOMY* starts on the Product Designer's Board

Interested in maintaining parts quality, *at greatly reduced costs?* Then you have practical reasons to be interested in powder metallurgy.

Hoeganaes, producers of superior grade Sponge Iron Powders, can helpfully suggest which products can be made by powder metallurgy . . . how manufacturing operations can be eliminated . . . how fabrication handling steps are simplified . . . how unusual physical properties can be achieved.

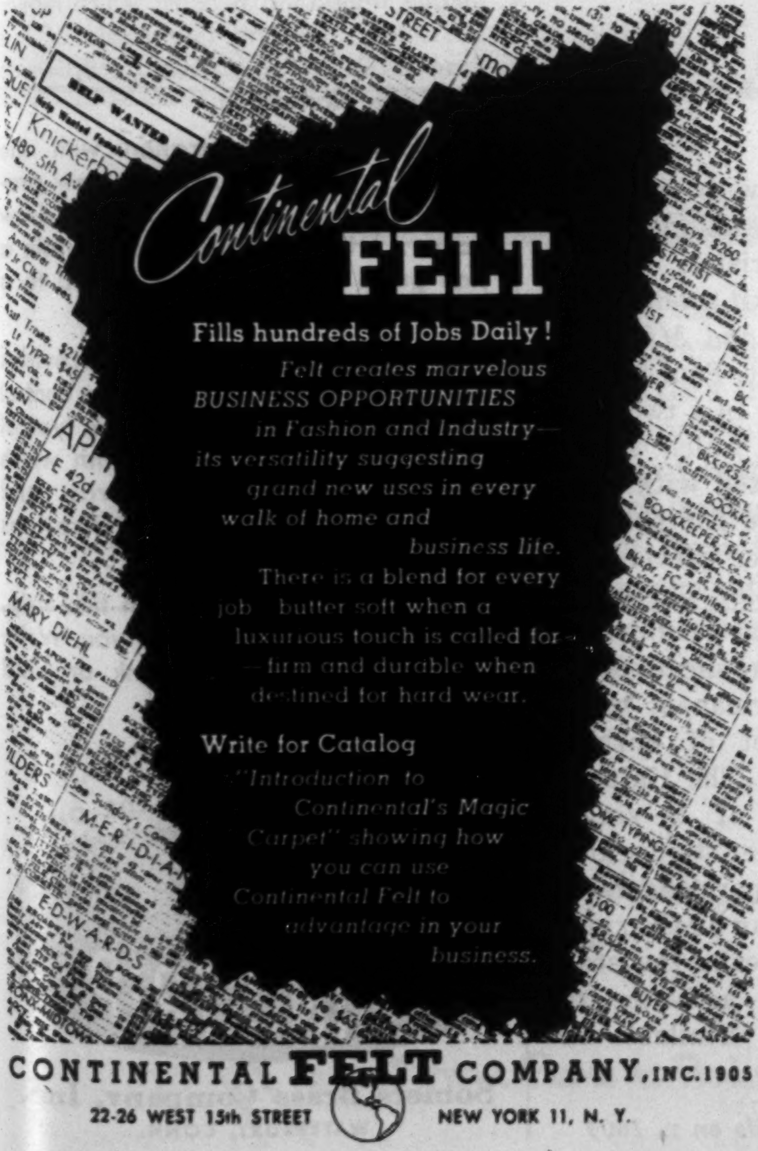
And above all, outline potential savings that are in store for you.



Write for your free literature. Read about the helpful, basic facts on powder metallurgy.

HOEGANAES SPONGE IRON CORPORATION

545 FIFTH AVENUE, NEW YORK 17, N. Y. • PLANT: Riverton, N. J.



Continental

FELT

Fills hundreds of Jobs Daily!

Felt creates marvelous BUSINESS OPPORTUNITIES in Fashion and Industry—its versatility suggesting grand new uses in every walk of home and business life.

There is a blend for every job butter soft when a luxurious touch is called for—firm and durable when destined for hard wear.

Write for Catalog

"Introduction to Continental's Magic Carpet" showing how you can use Continental Felt to advantage in your business.

CONTINENTAL FELT COMPANY, INC. 1905

22-26 WEST 15th STREET NEW YORK 11, N. Y.

For more information, turn to Reader Service Card, Circle No. 373

$AVINGS in $TEEL

NOW POSSIBLE WITH THE NEW

Alumicoat

Molten Aluminum Coating Process

In many cases, expensive high alloy strategic steels may be replaced with low alloy steels which have received the ALUMICOAT Molten Aluminum Coating Process. Under high temperature conditions, these low alloy steels would ordinarily oxidize and scale, but after the application of the ALUMICOAT Process, they have proven superior to strategic alloy steels.

TABLE SHOWING ALUMICOAT PROTECTION

Steel Samples	Temp. F.	Time hrs.	Change in Weight*
WITHOUT ALUMICOAT			
18-8 Chromium Nickel	1,350	24	– 17.0%
25-20 Chromium Nickel	1,350	4	– 8.3%
27% Chromium Steel	1,350	24	– 8.4%
WITH ALUMICOAT			
Plain Steel	1,350	192	+ 0.1%
18-8 Chromium Nickel	1,350	192	+ 0.1%
Plain Steel	1.700	48	+ 0.3%
18-8 Chromium Nickel	1,700	48	0.0%

*After corrosion scale was tapped off.

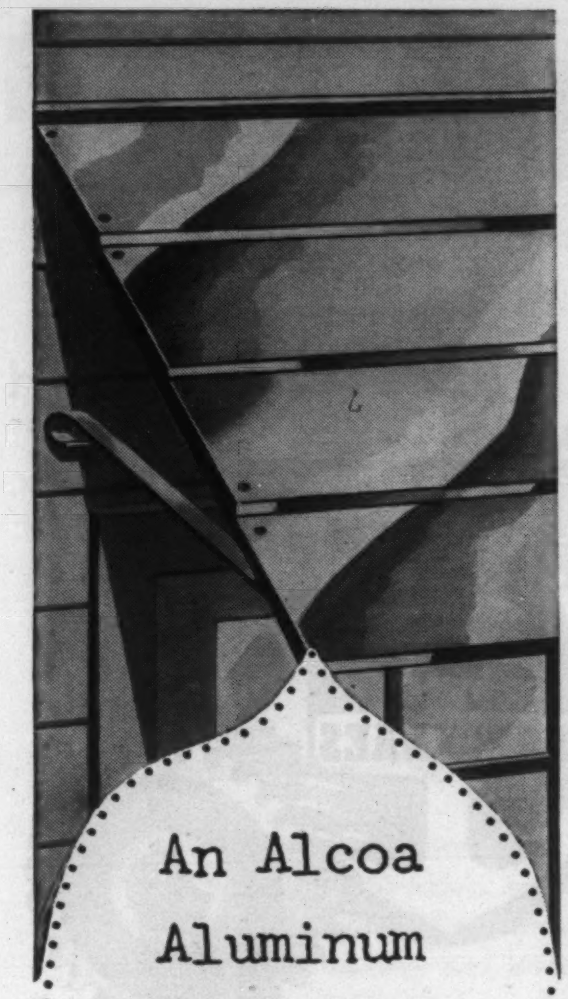
The above table showing ALUMICOAT protection, is a factual report of the protective capacities inherent i- the application of this process to different metals at different conditions.

The Alumicoat Process has been successfully applied to Jet Aircraft Components, Petroleum Refinery Equipment, Exhaust Manifolds, Diesel Engine Components, etc. Full details of the Alumicoat Process will be furnished upon request.

ARTHUR TICKLE ENGINEERING WORKS, INC.

21-C Delevan Street • Brooklyn 31, New York • MAin 5-4200

For more information, turn to Reader Service Card, Circle No. 379



An Alcoa Aluminum Fastener should be used here!

It's an aluminum awning assembly, worth the lasting strength of Alcoa® Aluminum Fasteners. You avoid galvanic and atmospheric corrosion. You get perfect color match; you get the very highest quality product. Your local Alcoa distributor has a complete stock.

P. S. In this awning assembly, we suggest an aluminum sheet metal screw from Alcoa's complete line of aluminum fasteners.

Aluminum Company of America
2251-L Alcoa Building, Pittsburgh 19, Pa.
Gentlemen:
Please send complete specification data and samples of your aluminum fasteners.
name____________________
title____________________
company____________________
address____________________

Always Fasten Aluminum with Alcoa Aluminum Fasteners

For more information, Circle No. 355

New Materials, Parts, Finishes

yards per pound of the continuous filament yarn.

Besides being bulky, bonded staple sliver is said to be compressible, tough when impregnated, compatible with many resins and rubber-base coatings and low in price. Cloth woven from the material has been adopted as a production item by weavers of glass cloth who are now selling initial production quantities to end users from inventory.

Owens-Corning is now producing a bonded sliver with E glass and E fiber. Smallest available as a standard item is ESE 40.0, 4000 yards per lb, and the largest is ESE 5.0, 500 yd per lb. The company will produce to any nominal yield between 4000 and 500 yd per lb, if a volume end use requires other than one of the standard sizes produced. Should demand arise, the material could be produced with either G or D fiber diameter or with C glass.

Improved Epoxy in Repair Kit

An epoxy resin with improved durability, heat resistance, and electrical characteristics is featured in a splicing kit produced by *Minnesota Mining and Mfg. Co.*, 900 Fauquier St., St. Paul 9. The resins are packaged in a two-compartment envelope which allows the resin to be mixed with catalysts in the package for field repair and splicing of power and communications cable. The splice is embedded in liquid resin which hardens without application of heat, forming a permanent moisture-resistant jacket of durable insulation material. The Unipack container consists of a single package with a barrier strip sealed across the middle separating resin and activator. Pulling on the sides of the container breaks the seal, allowing resin and activator to mix. The kits are available in three sizes.

(More New Materials on p. 160)

Somers

UNIGRAIN®

thin strip brass for deep drawing

Uniform fine grain size of Somers eyelet brass—less than .010 mm. (75X).

with **Fine Grain Finish**

Somers Brass Company is pleased to announce the availability of a new, unique annealing process which makes possible a uniform fine grain of less than .010 mm. which can be drawn to full 40% elongation.

Developed in cooperation with the Selas Corp. of America this new process makes it possible to deep draw Somers THIN STRIP and still obtain a fine grain which is easily buffed to a brilliant finish.

And this new Selas Furnace provides high production as well as close control of temper and uniformity. It is typical of the modern equipment with which Somers produces copper, brass and other alloys to rigid specifications between .010" and .00075".

If you have a problem with thin strip, let Somers experience help you. Write for confidential data blank or field engineer.

FOR EXACTING STANDARDS ONLY
MONEL•NICKEL•COPPER•ALLOYS
THIN STRIP

Somers Brass Company, Inc.
WATERBURY, CONN.

For more information, Circle No. 366

336,000
miles of extrusions!

Our extruders have turned out enough plastic and rubber extrusions to reach to the moon and halfway back. In compiling this vast experience General Tire's Industrial Products Division has supplied thousands of original equipment manufacturers with just about every known type of extrusion. No job is too large, too small or too complicated for our design and production staff. Perhaps *you* can benefit from the fantastic extrusion mileage we've accumulated down through the years.

For literature or further information write to The General Tire & Rubber Company, Wabash, Indiana, Department E3.

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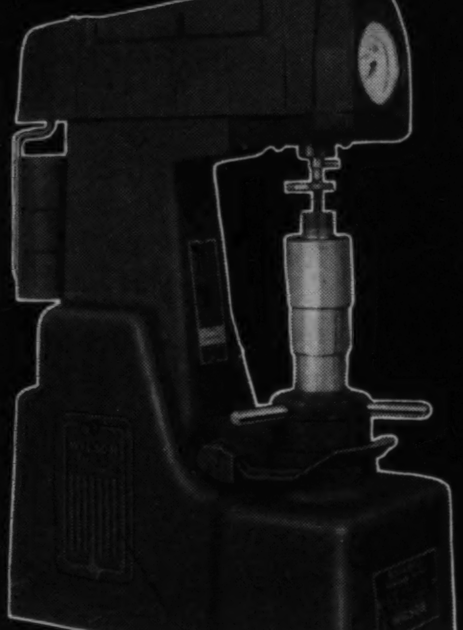
Industrial Products Division
WABASH INDIANA

"From Plans to Products in Plastics and Rubber"

For more information, turn to Reader Service Card, Circle No. 447

an ACCO product

Wilson "Rockwell"* Hardness Testers



Tests with INCREASED SPEED... Accurately

Y Model Motorized Hardness Tester

Requires fewer operating steps... *Because*

IT'S MOTORIZED

• Here is the motorized operating procedure made possible by the new WILSON "Rockwell" Y Model Motorized Hardness Tester—

1 Place specimen upon anvil or table.

2 Elevate test piece into test position. (With the new Set-O-Matic Dial Gauge, the large pointer will then automatically point to zero.)

3 Tap depressor bar to apply Major Load. When Major Load is fully applied, the Motorized Mechanism takes over—completes the test cycle—removes the Major Load.

4 Read "Rockwell" Hardness Number. Then, lower elevating screw to remove test piece.

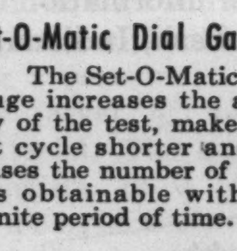
For complete information about the WILSON Y Model, or any others of the complete line of WILSON "Rockwell" Hardness Testers, write or call today. A WILSON hardness testing expert is available to consult on your specific requirement.

**Trade mark registered*

Illuminated Dial Gauge

(1) Affords clear and easy reading. Readings are easily taken wherever your "Rockwell" Tester is located—whatever the lighting conditions of the room.

Indenter light (2) is directed towards the test area, making it easy to locate the exact area of test at all times.



Set-O-Matic Dial Gauge

The Set-O-Matic Dial Gauge increases the accuracy of the test, makes the test cycle shorter and increases the number of readings obtainable within a definite period of time.

ACCO

Wilson Mechanical Instrument Division
AMERICAN CHAIN & CABLE
230-E Park Avenue, New York 17, N. Y.

for Better Value

For more information, turn to Reader Service Card, Circle No. 466

New Materials, Parts, Finishes

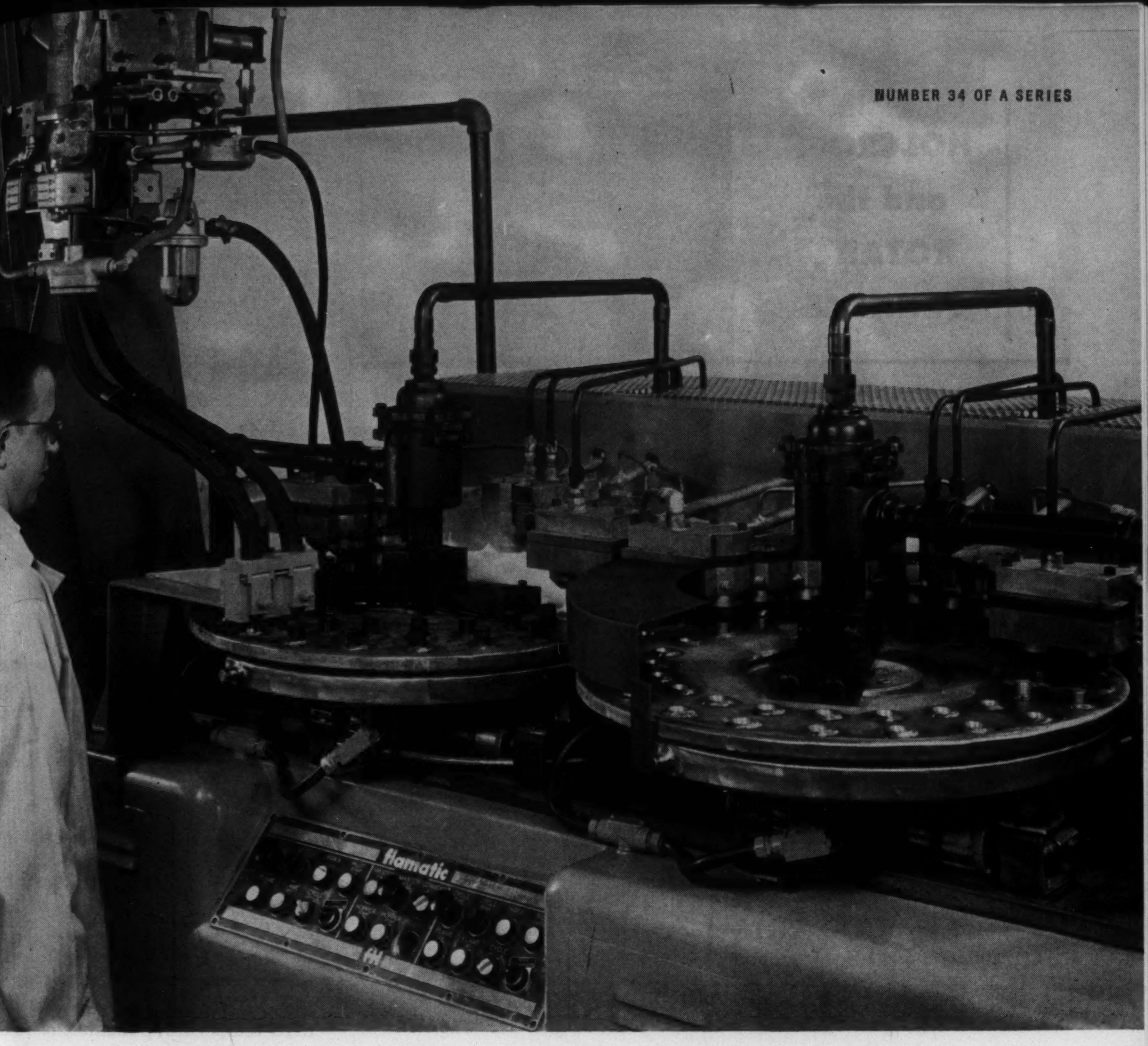
High Finish on Stainless Wire

Stainless steel wire with a mirror-like finish is being supplied in diameters of 0.030 to 0.090 in. by *National-Standard Co.*, Niles, Mich. It has a maximum tensile strength of 250,000 psi. According to National-Standard, the finish on the wire is perfectly smooth, free from scratches or flaws and for many end uses requires no additional finishing operations. The new wire is said to be rounder in shape than diamond-drawn wire and for most applications costs no more than regular stainless wire. Suggested uses include auto radio antenna tips, safety pins, kitchen utensils and toys. Where electropolishing is required for an extra fine finish, the as-drawn finish substantially reduces polishing time.

Fast Drying Primer

A protective primer which dries in 10 min at 85 F has been marketed by *Carboline Co.*, 331 Thornton Ave., St. Louis 19, Mo. Called Rustbond Primer No. 6, it can be applied over wirebrushed, rusty steel, sand-blasted steel and clean cold rolled steel and applies at a dry film thickness of 2 mils with a coverage of 230 sq ft per gal. It is said to have high resistance to alkalies and acids and good resistance to solvents and will improve topcoat performance of maintenance vinyls, phenolics, alkyds, chlorinated rubbers, neoprenes, oil base paints and furans. Since

NUMBER 34 OF A SERIES

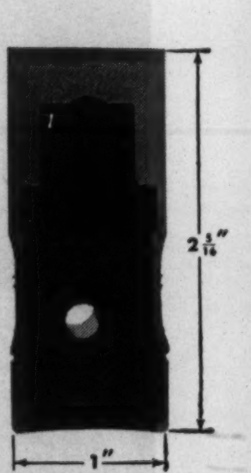


fully automated flamatic hardens 3600 parts/hour continuously

3600 hydraulic valve lifters per hour are continuously conveyed from a hopper to "carousel" type fixtures on this Cincinnati Flamatic hardening machine. The carousels index automatically after each heating cycle to bring a new pair of parts into position. Each lifter is selectively hardened to RC 57-61, to a $\frac{3}{32}$" depth, and dropped into the oil quench. This is another demonstration that Cincinnati Flamatic engineers can match unusually high production rates and tight heating specifications by combining standard components with ingenious tooling.

Control cabinet, quench tank, and conveyor are standard; hopper-fed loading mechanism, turntables, and flame heads are special.

Look into Flamatic-hardening as a new approach to your heat treating problems. Bulletin No. 1861-M gives a wealth of good examples.

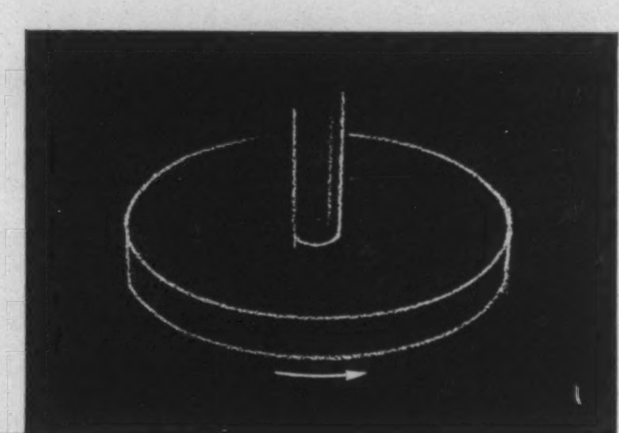


cross-section showing hardness pattern

CINCINNATI **flamatic**

PROCESS MACHINERY DIVISION
THE CINCINNATI MILLING MACHINE CO.
CINCINNATI 9, OHIO, U.S.A.

HOLCROFT and the ROTARY FURNACE



high production in small space

Production rates frequently bog down when floor space limitations prohibit large equipment purchases.

That's why—when the problem is heat treating—many companies turn to Holcroft for answers. Experience—imaginative engineering—versatility of products—all team up to provide answers.

For example, the solution to the problem above could conceivably be a rotary furnace: one with a single door for loading and unloading and a rotating hearth which carries the stock through the heat treat cycle. In this furnace, the hearth can be of a heat-resistant alloy or a refractory material. Or the furnace can be tunnel-type, grid-type, drum-type, or rotating retort. And, finally, the hearth can be suspended from above or supported from below.

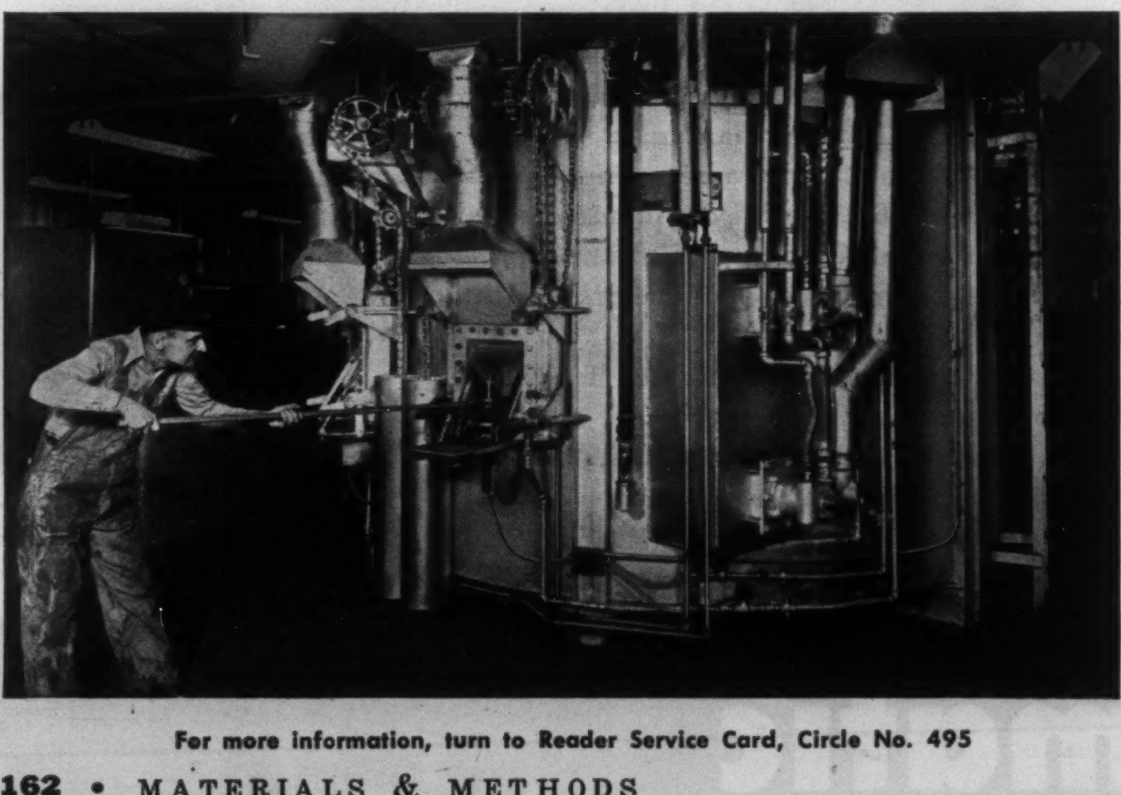
Of course, this is only one of the many kinds of stock handling which might be suggested by Holcroft. Your problem probably will be different and Holcroft probably will have the answer.

Write today for a copy of Holcroft's illustrated book: "Blazing the Heat Treat Trail." It's bound to give you food for thought.

4875

HOLCROFT AND COMPANY
6545 EPWORTH BOULEVARD • DETROIT 10, MICHIGAN
PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

CHICAGO, ILL. • CLEVELAND, OHIO • DARIEN, CONN. • HOUSTON, TEXAS • LOS ANGELES, CALIF. • PHILADELPHIA, PA.
CANADA: Walker Metal Products, Ltd., Windsor, Ontario



For more information, turn to Reader Service Card, Circle No. 495

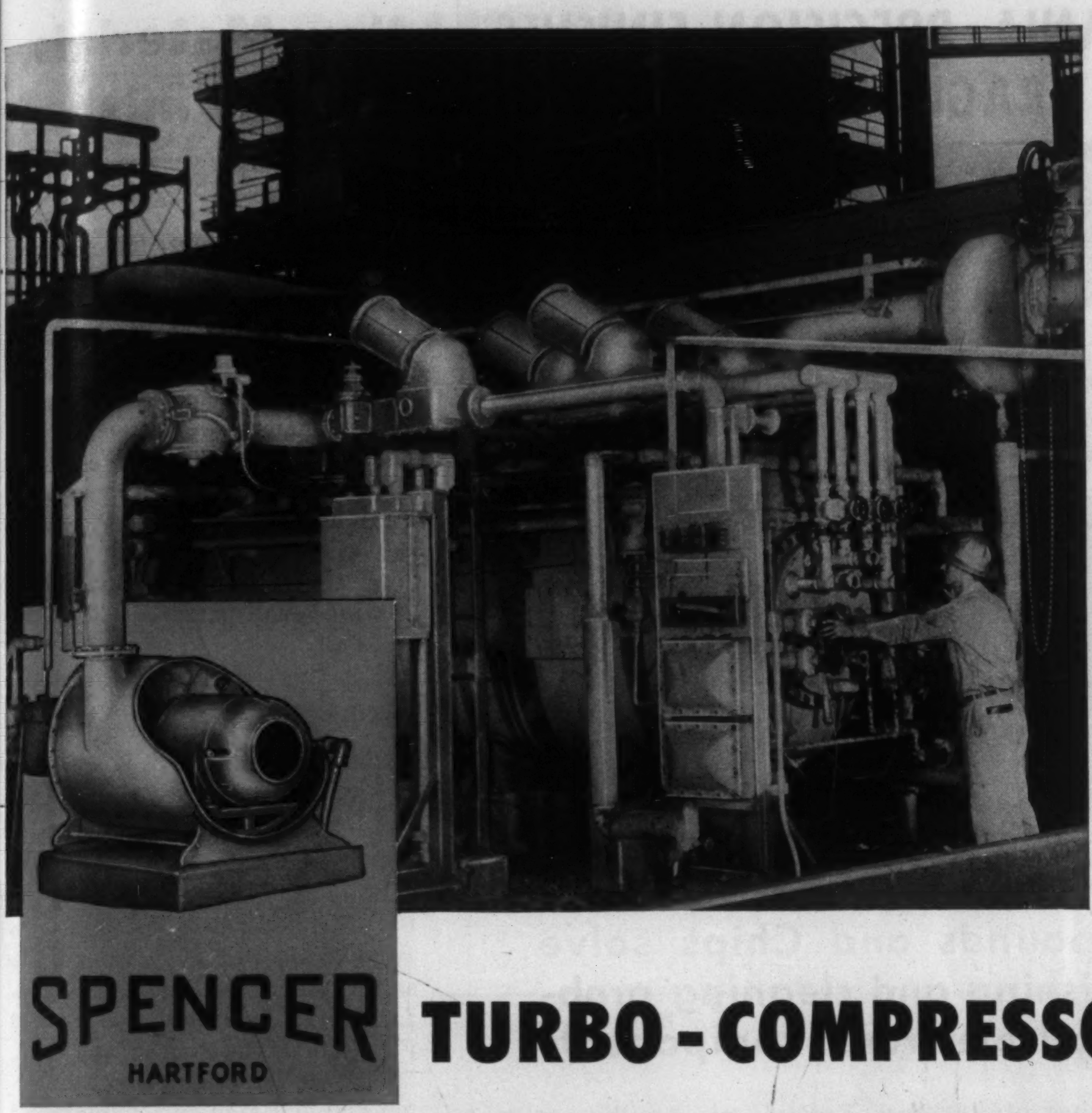
Primer No. 6 is compatible with all these coating materials, stocking of various different types of primers can be eliminated. The prime coat is said to be tough and flexible and will not peel or flake.

Impregnant for Electrical Wiring

A heat-reactive insulating varnish for impregnating electrical coils for stationary and moving parts on Class B equipment has been developed by *Schenectady Varnish Co.*, 200 Congress St., Schenectady 1, N. Y. Designated No. 99B. the varnish may be applied by commonly used dip methods and dip tank stability is said to be good, with no tendency to jell. Xylol thinner may be used in any proportion without danger of precipitation. It is heat-reactive and will cure in 2 to 4 hr at 275-300 F. Further curing of 2 to 4 hr at 355-365 F improves and stabilizes electrical properties such as power factor, dielectric loss and high temperature insulation resistance. Bonding strength and adhesion to enameled magnet wire are also increased by additional curing. The varnish is said to be particularly well suited for application over magnet wire coatings such as Isonel, silicone, Formvar or nylon. Impregnated coils can be operated at temperatures up to 280 F.

Coating for Aluminum Dries Rapidly

A cold chemical coating material for aluminum which provides either a soft or high gloss finish and requires only 1 minute for drying has been developed by the *Birchwood Chemical Co.*, 4500 W. 44th St., Minneapolis. Called Alumblack, the material can be dipped, sprayed or applied with rag or brush. There is no surface spotting or density variation, and if left



TURBO-COMPRESSOR

on SUN OIL'S "MAGIC MILL"

by

C. M. KEMP

Manufacturing Company

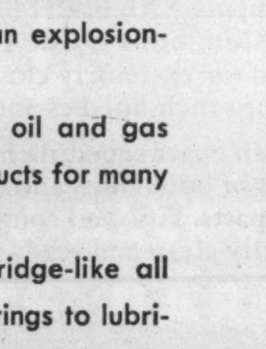
This Kemp Generator produces 60,000 cu. ft. of inert gas per hour for purging pipelines, tanks and crackers at Sunoco Plant No. 5.

The heart of this "Magic Mill" is the Kemp Industrial Carburetor at the left. Air is supplied by a Spencer Turbo with an explosion-proof motor.

Kemp is one of more than thirty manufacturers of oil and gas equipment that have used Spencer Turbos on their products for many years.

The reasons: Extreme reliability because of the bridge-like all metal construction, wide clearances and only two bearings to lubricate. No special foundations required. Blast gates control the air, calibrated ammeters indicate the output and power used is proportional to the air required at any time.

A hundred uses for Spencer Turbos are indicated in Bulletin No. 107. Turbos are described in Bulletin 126.



THE SPENCER TURBINE COMPANY

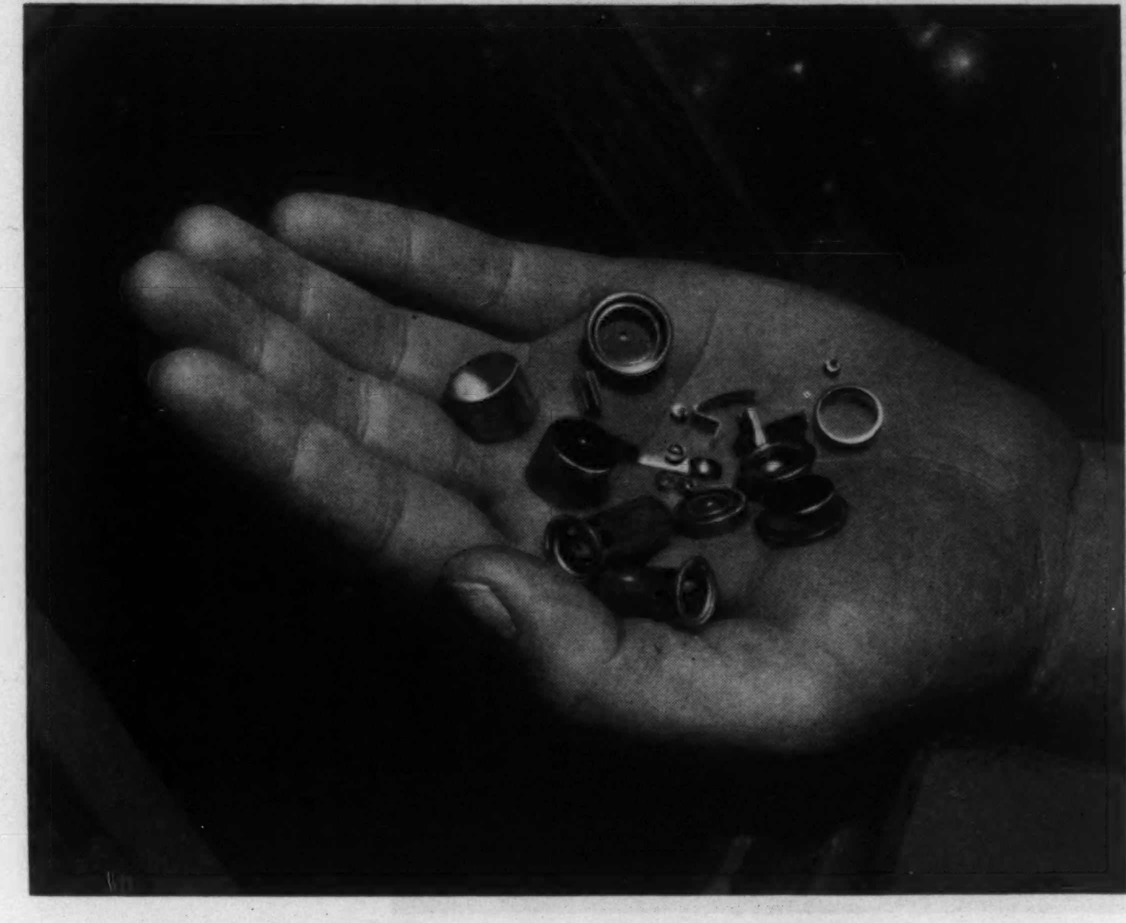
SPENCER
HARTFORD

HARTFORD 6
CONNECTICUT

Manufacturers of Turbo-Compressors and Heavy Duty Vacuum Cleaners

For more information, turn to Reader Service Card, Circle No. 311

HOW SYLVANIA PRECISION-FINISHES A MILLION FRAGILE PARTS A DAY



Lorco Compounds and Chips solve intricate finishing and cleaning problems on small electronic components

In Sylvania Electric's new plant in York, Pennsylvania, a million or more precision electronic parts are turned out every day. Some of the tolerances are as close as ±.0005 inch.

Meeting these high production demands alone presented a tough problem to plant engineers. But, there still remained the tremendous hurdle of de-burring, finishing and cleaning these myriads of tiny parts.

Hand finishing was out of the question because of time and cost barriers. Experiments with barrel finishing proved that Lorco Compounds and Fused Aluminum Oxide Chips held the solution. Not only did they maintain the extremely close tolerances, but they provided the required low micro-inch finishes and chemically clean surfaces as well.

Today, an exact schedule has been worked out to control the amount and type of both chips and compounds for each of the variously shaped, minute parts. Finished components, by the million, come out burr-free, chemically clean and ready for installation.

Lorco Chips and Compounds are offering truly amazing answers to the problems of scores of manufacturers . . . for thousands of parts . . . of all shapes and sizes. Write for detailed information about our free sample processing service and your copy of the new manual, "The Lorco Method of Precision Barrel Finishing."

Lorco

LORD CHEMICAL CORPORATION

2068 SOUTH QUEEN STREET YORK 4, PENNSYLVANIA

MANUFACTURERS OF BARREL FINISHING COMPOUNDS
TUMBLING BARRELS — MEDIA AND AUXILIARY EQUIPMENT

For more information, turn to Reader Service Card, Circle No. 490

New Materials, Parts, Finishes

unrubbed a dull gloss finish results. A high-gloss, satin-smooth finish can be obtained by rubbing. The material is said to penetrate the oxide film on the surface of aluminum, therefore coatings produce no dimensional deviation. Though the material provides corrosion protection, there is insufficient data as yet to say what degree. Alumblack is said to be particularly applicable for retouching and coating small parts.

Inorganic Base Zinc Coating

A newly developed protective coating, called Dimetcote is a 100% inorganic zinc coating containing no oils or resins. It is said to provide protection similar to galvanizing and good resistance to salt water. According to the manufacturers, *Amercoat Corp.*, 4809 Firestone Blvd., South Gate, Calif., Dimetcote is resistant to weathering and abrasion and is unaffected by solvents and petroleum products. The bond produced between coating and base metal is said to be chemical as well as mechanical and the film cathodically inhibits corrosion of adjacent areas of bare steel. The coating is said to be applicable to a variety of industrial installations such as structural steel, floating roof tanks, barges, marine drilling towers, ship decks and dam gates.

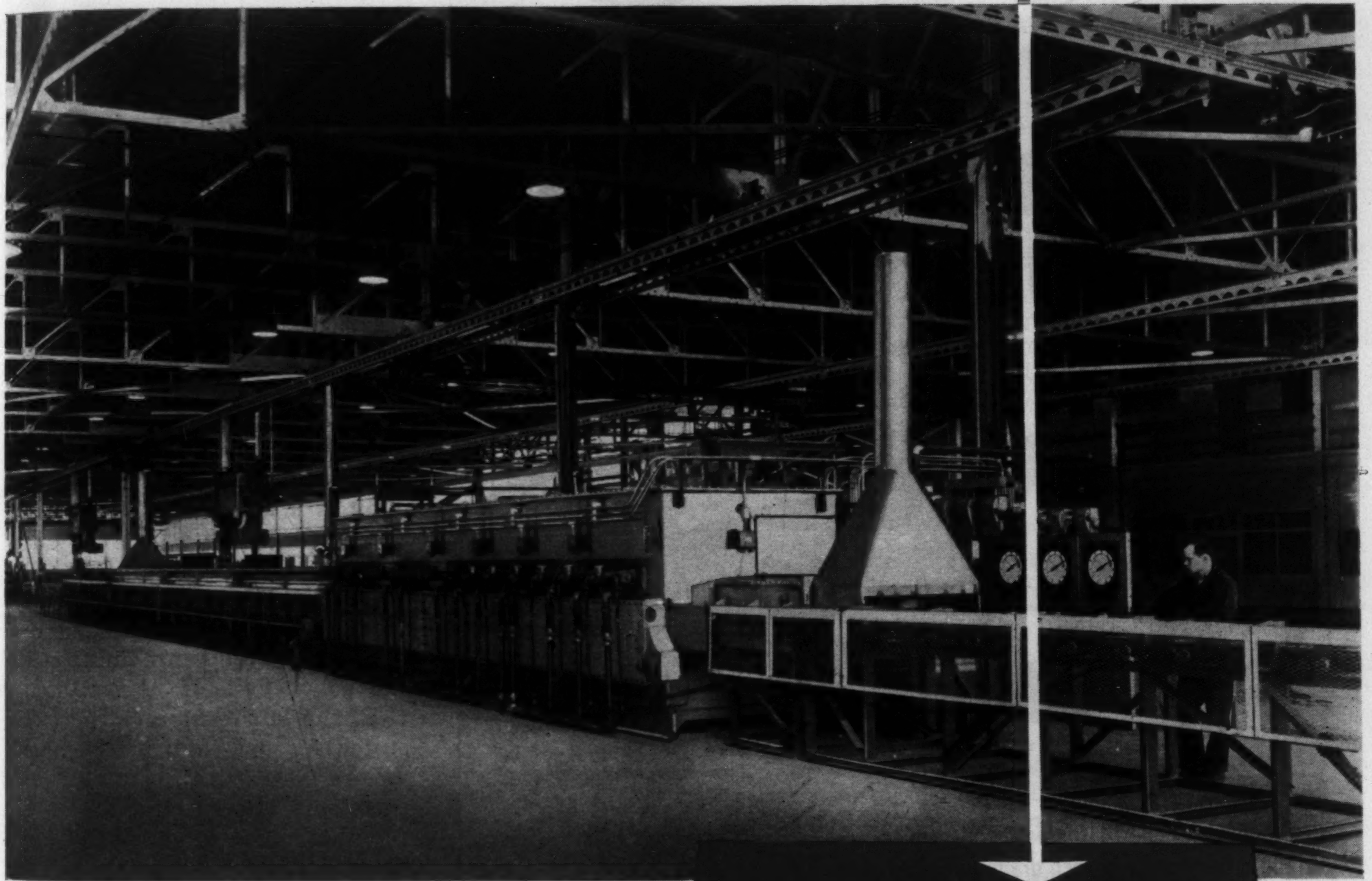
Enameled Aluminum Foil

Porcelain enamel in a wide range of matte and glossy colors on 50 in. wide aluminum foil is being produced and sold in 500 ft coils by *Keasbey Corp.*, Keasbey, N. J. The foil can be produced as thin as 0.0005 in. The material is said to be suitable for facing all types of backing materials, such as plywood, pressed wood, fiber-, asbestos-, and gypsum-board. It is

(Continued on p. 168)

DREVER

ROLLER HEARTH *Bright Annealing* FURNACES



12

FOR

CARBON and ALLOY STEEL PARTS, BARS or TUBING

Shown above:

Controlled Atmosphere Furnace
Radiant Tube, Gas-Fired
Capacity, 3,000# /hour
Alloy Tubing 1/8" O.D. to 2½" O.D.
Overall, 176 ft. long x 7'-6" wide

Also Available:

Gas or Electric Furnaces for Stainless Steel Annealing with or without Controlled Atmosphere

Installed at the plant of Sawhill Tubular Products, Inc.

DREVER CO.
RED LION RD. & PHILMONT AVE.,
BETHAYRES, PA.

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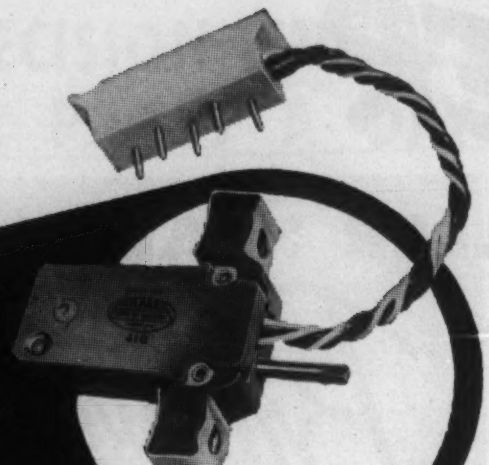
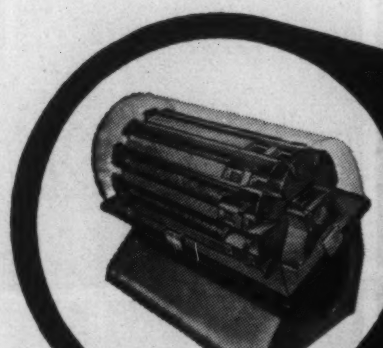


PRECISION MOLDING TO .001"...

IBM CHOOSES **MYCALEX®** **410**



ABSOLUTE DIMENSIONAL STABILITY...

IBM chooses Mycalex 410 glass-bonded mica for 200 critical parts in each drum assembly of the new Type 650 Magnetic Drum Data Processing Machine because this combination of precision molding and dimensional stability is essential for the accurate reading, under varying conditions, of up to 20,000 digits of stored data.

And these other properties too, have helped make Mycalex world-famous as "the most nearly perfect insulation":

- withstands extreme operating temperatures
- offers total arc resistance
- possesses low loss and power factors
- is moldable with tight inserts

Write today for information concerning your particular insulation problem. Address inquiries to General Offices and Plant: Dept. 124, P.O. Box 311, Clifton, New Jersey.

World's largest manufacturer of glass-bonded mica products

MYCALEX CORPORATION OF AMERICA

Executive offices:
30 Rockefeller Plaza
New York 20, N. Y.

SINCE 1919
MYCALEX
THE INSULATOR

For more information, turn to Reader Service Card, Circle No. 506

being supplied at prices competitive with conventional organic coatings. Possible applications include wall-boards, ceiling tiles, sink and counter tops, cabinet fronts, and door panels.

Silicone Lubricants Commercially Available

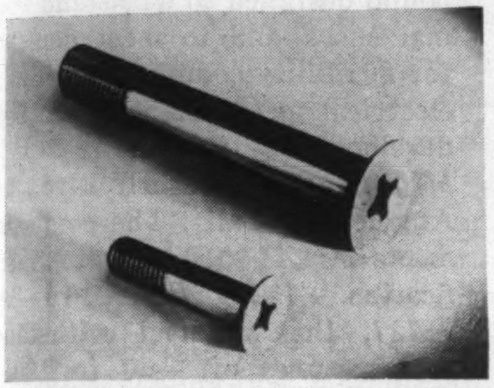
Silicone lubricants for jet engine and industrial uses are now commercially available from *General Electric's Silicone Products Dept.*, Waterford, N. Y. Versilube F-50 fluid and Versilube G-300 grease are said to have approximately the same degree of lubricity as petroleum oils and greases, yet retain all of the typical silicone characteristics. They are effective over an operating temperature range of −100 to 400 F. Versilube F-50 is a silicone polymer which does not require additives. Characteristics such as "oiliness," low pour point, excellent temperature-viscosity properties and high temperature stability are inherent in the polymer itself. According to G-E, the lubricants are especially suited for use in industries such as the glass, steel, ceramics, and petroleum. Potential areas of use for the lubricants include sleeve bearing and ball bearing motors, clocks, timers, instruments, fluid transmissions, refrigerators, hydraulic systems, and ball bearing or chain conveyor systems.

Epoxy Resin Has Low Toxicity

A new fluid epoxy casting resin, called Epocast 13, uses no amine hardeners, making the material relatively toxic-free. Mixed with appropriate amounts of hardener the resin has a pot life of 8 days, making it particularly useful where numerous pours must be made. Curing temperatures are

For more information Circle No. 534

200-250 F. Developed by *Furane Plastics, Inc.*, 4516 Brazil St., Los Angeles 39, Calif., the material is expected to find use in potting and encapsulation of electrical components and as a filled material for making large cast shapes. It is available in kit quantities for ease of mixing.



Flush-Head Titanium Bolts

Titanium flush-head shear bolts, NAS-333 series type aircraft fasteners, are being produced by *Standard Pressed Steel Co.*, Jenkintown, Pa. The Hi-Ti 100-degree flush head bolts are being formed from a 4 aluminum-4% manganese titanium alloy and are intended as a substitute for conventional alloy steel bolts, with a resulting weight saving of approximately 75%.

Company test results indicate a shear strength of about 113,500 psi for ¼ in. dia bolts and 109,000 psi for ⅜ in. dia titanium bolts, comparing favorably with minimum shear requirements of 95,000 psi for fasteners of this type. According to SPS the ¼ and ⅜ in. dia bolts show endurance limits of 55,000 and 40,000 psi respectively. The NAS-333 type Hi-Ti shear bolts are being produced in sizes ranging from ¼ to ½ in. diameters. Shear strength in all sizes exceed 95,000 psi and tension fatigue characteristics are said to be equal to, or exceed those of conventional alloy steel fasteners of

FACTS ABOUT ATLANTALLOY
PRECISION PLASTER MOLD CASTINGS

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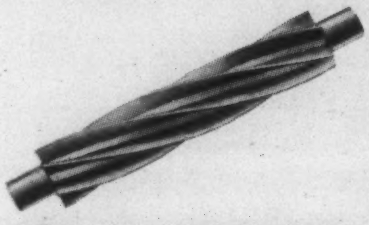
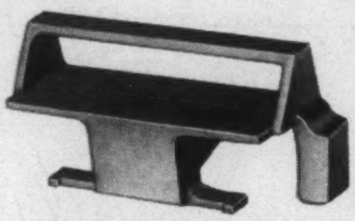
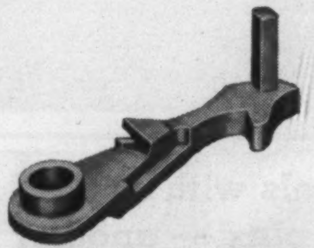


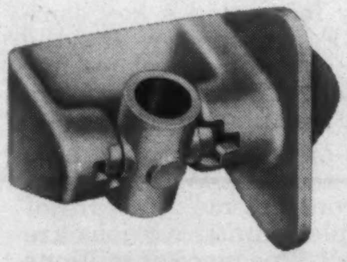
One-piece cast ice cutter for York Corporation's Automatic Ice Maker replaced fabrication of several stainless steel parts.



Cast brush holder for General Electric aircraft generators lowered costs, provided closer tolerances and increased strength.



Lever casting of *Atlantalloy* #31 manganese bronze with tensile strength of 100,000 psi for Sargent & Greenleaf's manipulation-proof lock.



Rugged skirt door operating mechanism cast for Pennsylvania Railroad cars manufactured by the Budd Company.

Today, ATLANTALLOY CASTINGS are used where precise dimensions and high physical values *plus* economy are essential. These unique precision plaster mold castings can improve *your* product design and reduce *your* costs:

PRECISION — Meet precision machining tolerances. Average limits, ± .005 on one side of parting line. Minimal or no machining or finishing.

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EXCLUSIVE CASTING FEATURES — No gas formation when metal enters mold, and no ebullition of liquid metal. Self-venting molds yield to metal, cool slowly. Castings are practically stress-free with superior grain structure. Loose cores permit "impossible" designs. Finishes are exceptionally smooth and clean.

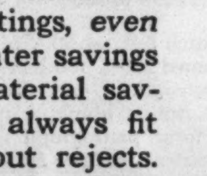
ECONOMY — Major savings in machine work because of high finish, uniformity and accuracy. End costs below machined parts from rougher-type castings, *even for limited volume runs.* Greater savings for large runs. Time and material savings since uniform castings always fit your jigs and fixtures without rejects. Tool life extended because castings have no blow holes, hard spots, or inclusions.

SALES REPRESENTATIVES

Middle Atlantic States — Beemer Engineering Co., 401 North Broad St., Philadelphia 8, Pa.

New England — J. C. Tarbel Associates, Inc., 64 Park St., Springfield 2, Mass.

More facts on "High Quality Precision Castings for Industry". Write for your free copy!



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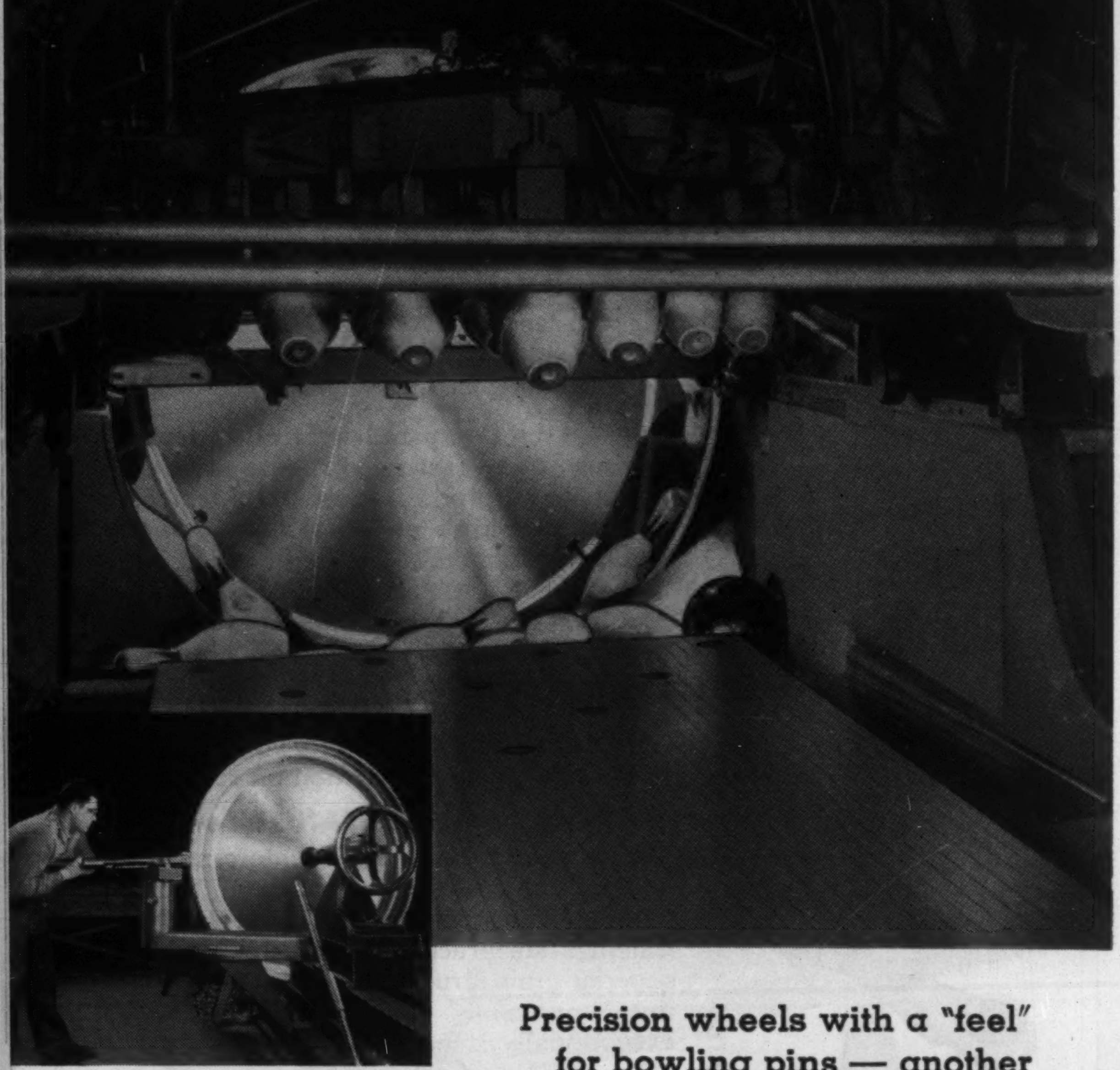

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On each 5-ft. wheel, Spincraft assumed 100% fabricating responsibility: deep draw, spin, punch, blank, stamp and form, pantograph (chamfer), surface finish, drill, rivet, carton and ship. Operator (above) is spinning the 1/8-in. thick sheet of tough 52S aluminum alloy. Cross-section of basic wheel (right) shows unusual contour requirements. Raised segments are 1/8-in. cold rolled steel.

Precision wheels with a "feel" for bowling pins — another example of Spincraft's fabricating skill

By setting pins faster, American Machine and Foundry's automatic pin spotter gives more bowlers more opportunities for better scores! Spincraft is proud to have successfully fabricated a key component of the AMF pin spotter. It's the large-diameter pin elevator wheel — our solution to a difficult production problem for this well-known manufacturer.

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New Materials, Parts, Finishes

the same type. Tension-tension fatigue data at a stress level of 6000-60,000 psi, based on thread root area are supplied with each lot produced.

Elastomeric Potting Compound

A polysulfide-based potting compound designed to withstand thermal shock and to meet demands for flexibility combined with high electrical performance has been developed by *Coast Pro-Seal & Mfg. Co.*, 2235 Beverly Blvd., Los Angeles 57, Calif. The compound meets MIL-S-8516A (Aer) Specification. Designated Pro-Seal #727, the material withstands temperatures of −60 to 180 F and forms a strong, resilient rubber of low shrinkage. Base material is approximately 97% solids. Its pourable viscosity allows entrapped air to escape, producing a high density in the cured material. The cured material is resistant to gasolines, oils, greases and other petroleum products, including pressure lubricants and standard red hydraulic oil. It is exceptionally resistant to water and weathering.

It is a two-part, room temperature-curing material which should not be thinned. Cured material is light brown and weighs 15 lb per gal. As supplied, the pourable paste has a viscosity of 600 to 800 poise (#6 spindle, 4 rpm) and a working time of not less than 90 min under standard conditions of 77 ± 2 F and 50 ± 5% relative humidity. Increased temperatures shorten work life and decreased temperatures lengthen work life. Lower humidity tends to give longer work life with a subsequent lengthening of cure time. Higher humidity tends to shorten work life and cure time.

Fully cured, the material has relatively high tensile strength and elongation. Its electrical char-

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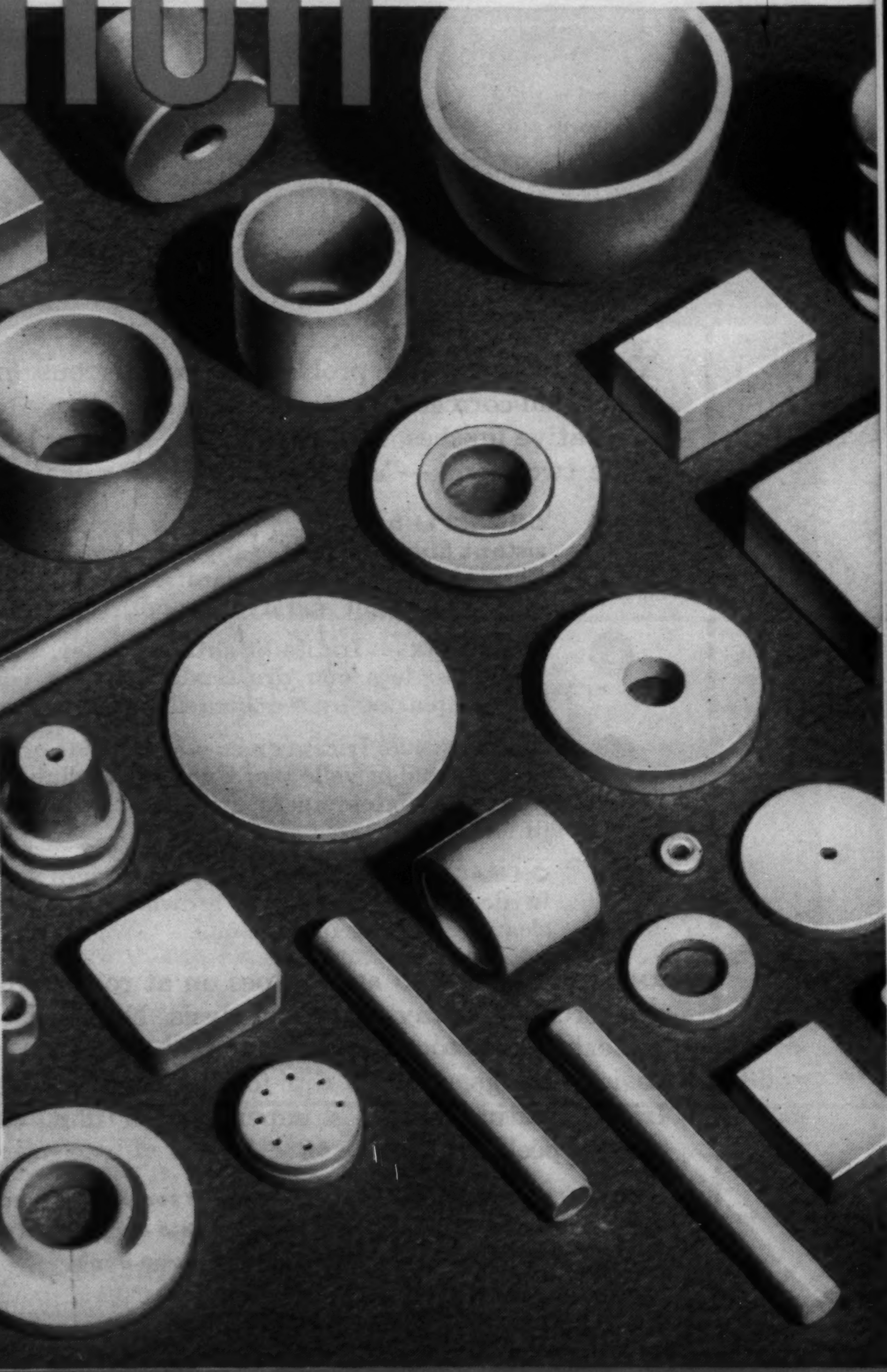

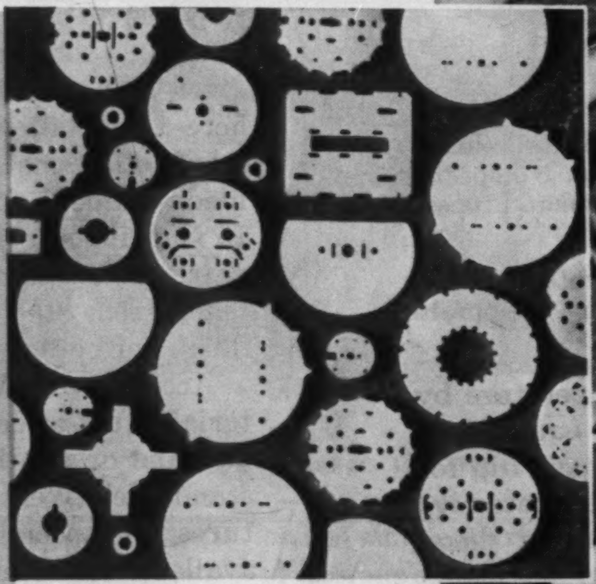

olume production complete range of precision parts, ding electron tube s processed to be highly porous, readily degassed, thicknesses as low as .009".

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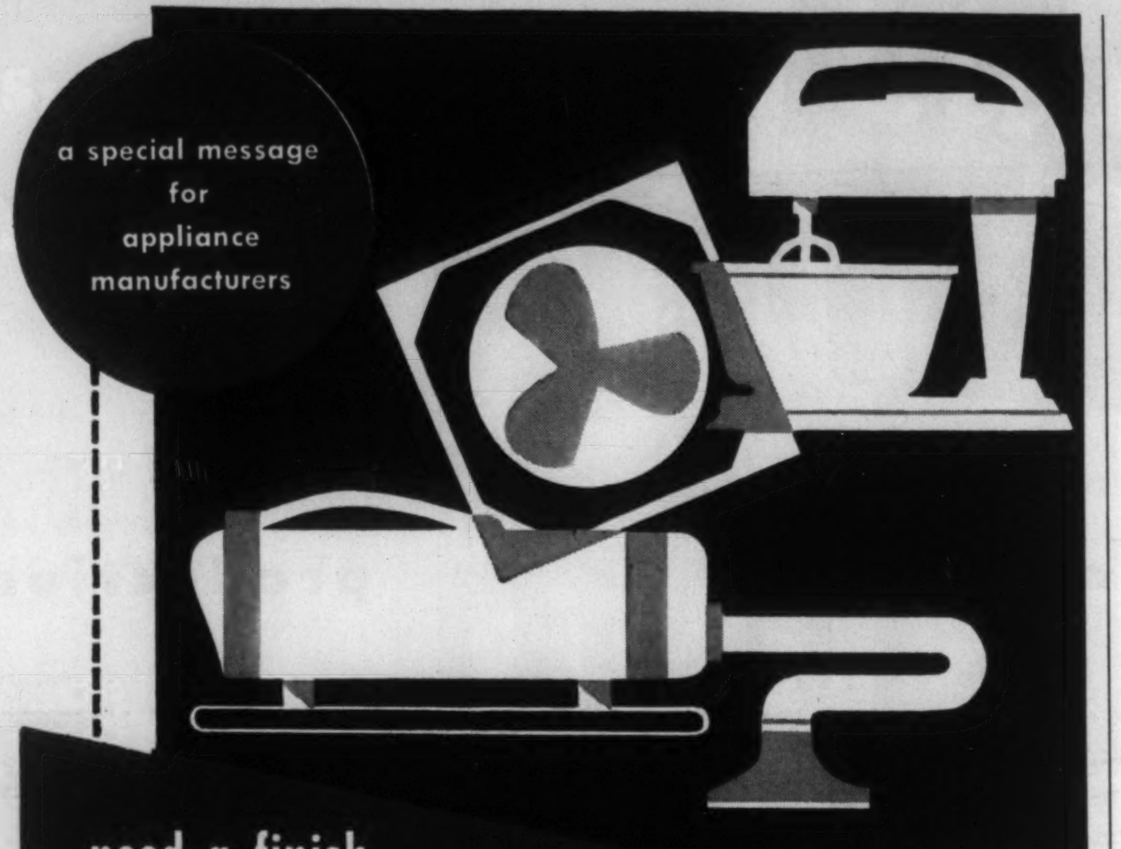

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acteristics in all cases are said to meet or exceed minimum values outlined in Table 1, page 3 of MIL-S-8516A (Aer). The compound should be applied to clean surfaces by pressure gun, pressure flow gun or spatula. Since the compound contains some solvent, it is flammable and proper precaution should be observed. The curing agent, Pro-Seal #727-A contains a lead compound, so excessive skin contact should be avoided.

Aluminum-Plastics Putty

A putty-like material consisting of atomized aluminum and a vinyl formulation is being marketed by *Woodhill Chemical Co.*, 1391 E. 33rd St., Cleveland, under the trade name Duro Plastic Aluminum. The material is ready to use as it comes from can or tube, and requires no catalysts or hardening agents. It is applied cold and air dries in a few hours. It will adhere to metal, wood, leather and many other materials and can be filed, sanded, drilled or tapped. It is primarily intended as a repair material for removing blemishes from steel castings or as a filler for other metal products.

According to Woodhill, the material is not affected by oil, water, gasoline or naptha and will withstand relatively high temperatures. A special solvent is also available for thinning the material to brushing consistency.

Translucent Cold Punching Laminate

A translucent paper-base phenolic cold punching laminate has been developed to aid in obtaining accurate registry in fabrication of printed circuits. Produced by *The*

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Slush molders particularly will appreciate the exceptional viscosity, stability and flow properties of pastes formulated from EXON 654. These pastes are unsurpassed for processing ease. They gell quickly. And they always coat the mold smoothly and evenly.

Whatever your particular problem, you're likely to find the specific remedy among Firestone's many Exon resins.

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And of growing importance are above-grade masonry water repellents made with LINDE Silicones that hate water. These "invisible raincoats" are protecting homes, schools, institutions, factories, against damage from water seepage for as much as ten years. They slash both interior and exterior maintenance costs, and preserve original building beauty and quality.

If you want a silicone that will make water "behave," or for some totally different use in your products, call on LINDE. Their wide experience and that of other Divisions of UNION CARBIDE puts a large store of industrial knowledge at your service. Write Dept. N-11.

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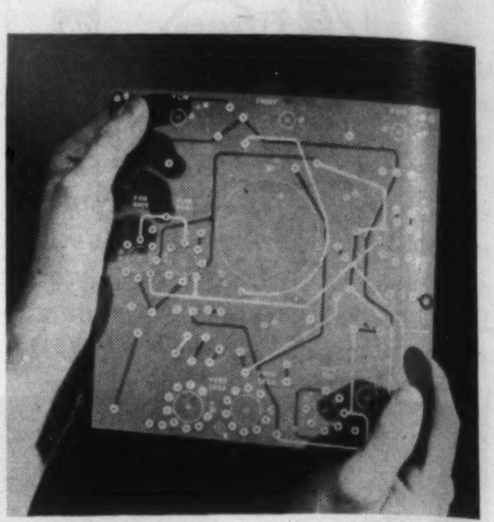
New Materials, Parts, Finishes



Formica Co., Cincinnati 32, Ohio, the XXXP-36 laminate is said to provide insulation resistance on the order of a million meogohms. The laminate punches cold in thicknesses up to and including 1/16 in., requiring no heating cycle. Thus the laminate is not subject to dimensional change due to unequal expansion and contraction. Other favorable characteristics include high dielectric strength, high heat resistance and superior bonding strength. The material may be used for applications other than printed curcuitry.

Flame-Sprayed Alumina Coatings

A flame-sprayed aluminum oxide coating process has been developed by *The Montaine Corp.,* 7127 S. Chicago Ave., Chicago 19. Similar to the technique developed by Armour Research (see MATERIALS & METHODS, September issue, page 96), the so-called Flame Rock coating is applied by spraying

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TWO HEADS ARE BETTER THAN ONE

Sometimes a double head is the only solution to your part or fastener problem. This steel spacer is an excellent example of a single double-headed part that has replaced a more expensive 3 piece part. Not only was the spacer itself much less expensive but actual assembly cost was cut almost 30%. HASSALL double-heading really paid off on this one.

Double-heading is only one example of the almost limitless possibilities Hassall cold-heading offers you. If you have a fastener problem just send us samples or specifications for a quotation.

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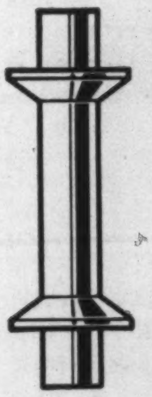


molten alumina powder on the surface to be coated. Montaine supplies the Flame Rock powder and the necessary equipment.

Flame Rock coatings are said to be approximately twice as hard as tool steel, with a melting point above 3600 F and provides good electrical as well as thermal insulation. The coating is unaffected by most corrosive agents including many molten metals, and is said to be resistant to chipping even under direct impact. A degree of porosity permits the coating to hold lubricants.

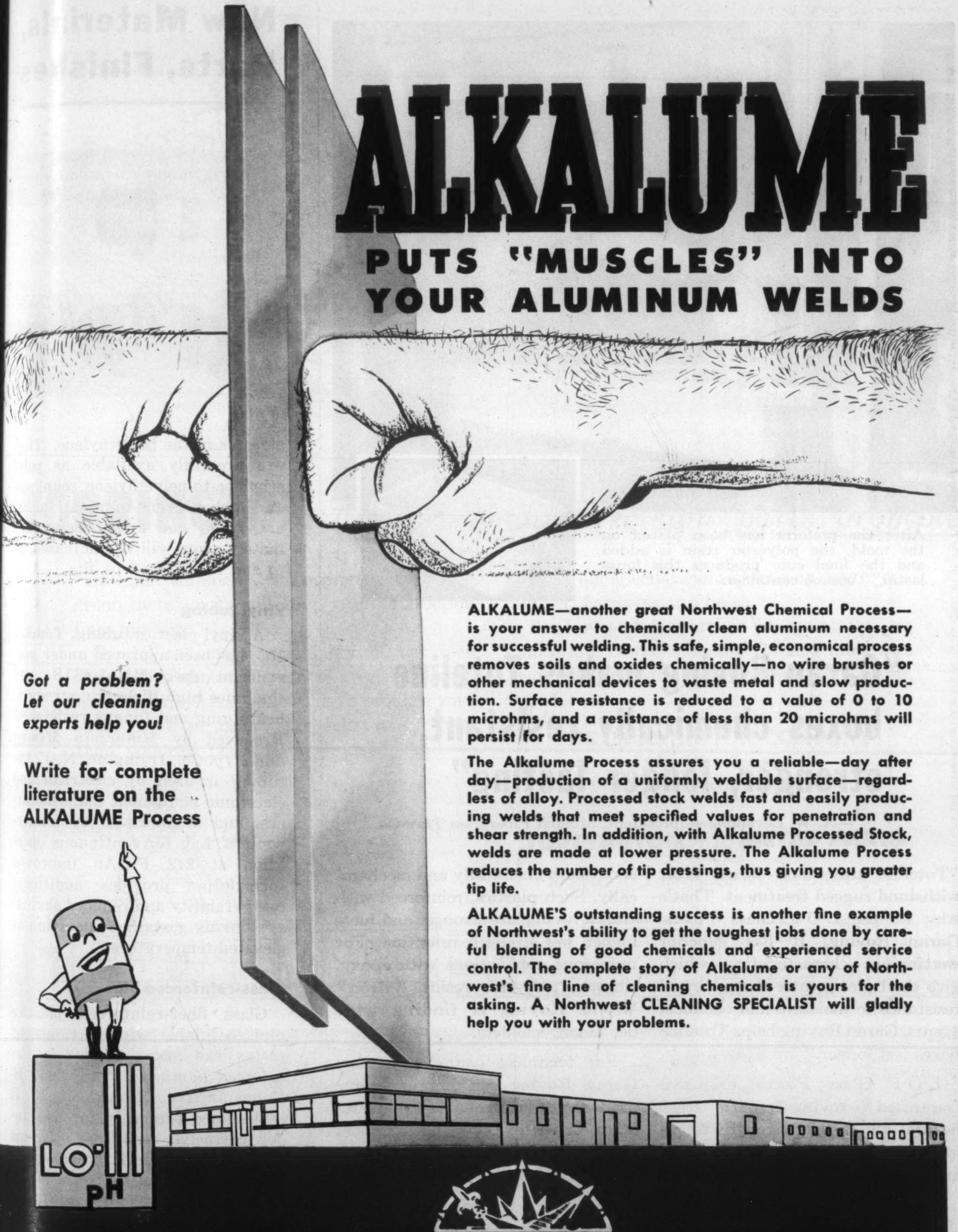
Coatings can be applied to a variety of metallic and nonmetallic materials, including steel, titanium, carbon, aluminum, magnesium, brass, copper and glass. It offers moderate-cost protection from wear, heat and many types of corrosion. Among suggested uses are foundry molds, and melting pots, pump linings, auto cylinder linings, tools and dies, jet engine and rocket parts, oil burner pots, bearing surfaces, aircraft wheel and brake assemblies, washing machine parts, lighting fixtures, welding equipment, abrasive products, valve seats and metal rolls.

Plastics Pipe and Fittings

Recently several companies have marketed a variety of new types and sizes of plastics pipe, both reinforced and unreinforced, and fittings for them. These are summarized below.

Fittings for polyethylene pipe

New type couplings and adapters for use with polyethylene pipe are being injection molded from rigid unplasticized polyvinyl chloride by *Wilmington Plastics Co.*, 810 S. Heald St., Wilmington, Del. The fittings are resistant to corrosion and form a tight joint without setting up undue compressive



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ALKALUME—another great Northwest Chemical Process—is your answer to chemically clean aluminum necessary for successful welding. This safe, simple, economical process removes soils and oxides chemically—no wire brushes or other mechanical devices to waste metal and slow production. Surface resistance is reduced to a value of 0 to 10 microhms, and a resistance of less than 20 microhms will persist for days.

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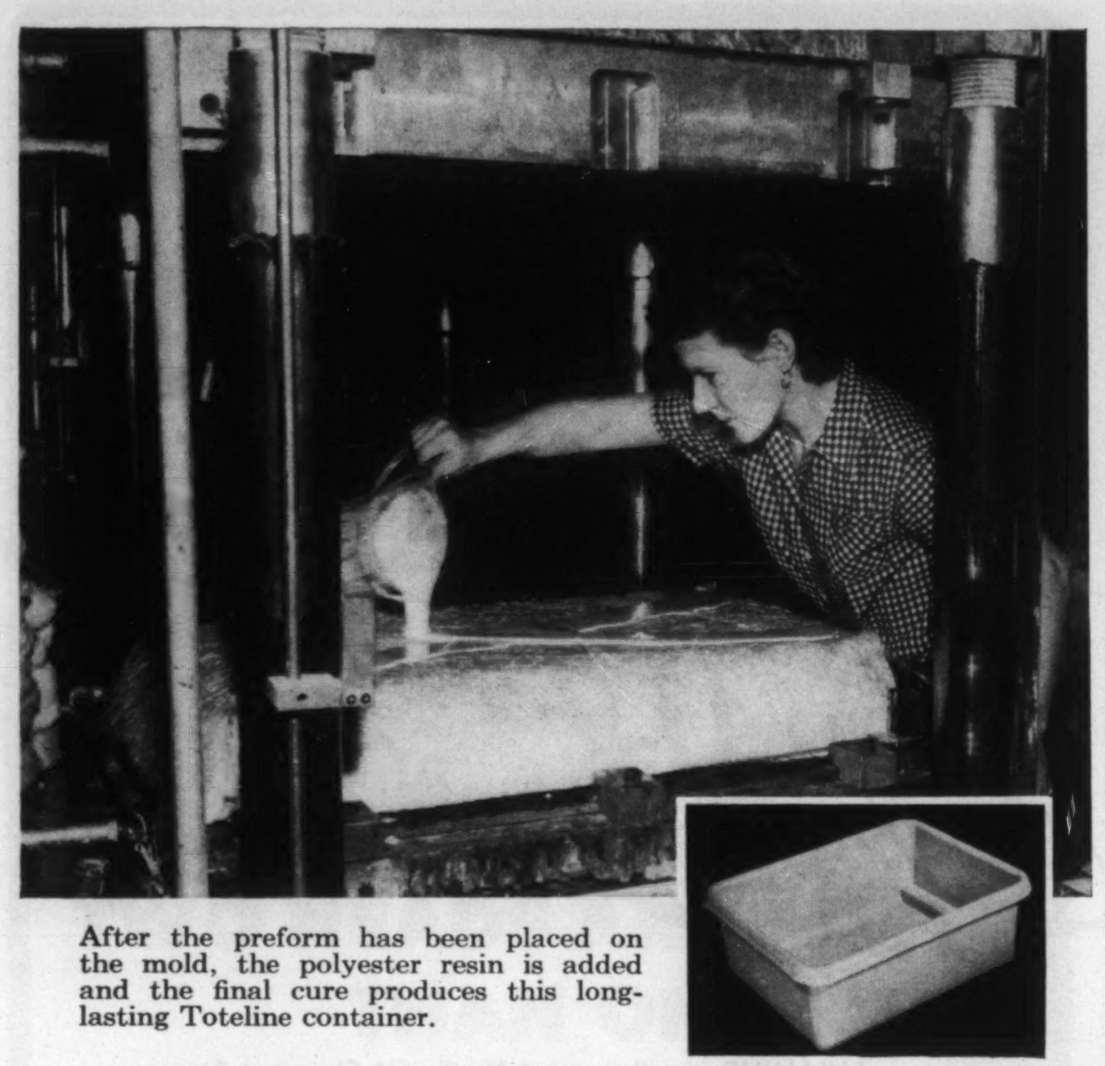

After the preform has been placed on the mold, the polyester resin is added and the final cure produces this long-lasting Toteline container.

"Garan Roving makes Toteline boxes chemically resistant, stronger, longer lasting"

—A. W. Levenhagen, president, Molded Fiberglass Tray Co.

"Toteline trays and boxes must withstand rugged treatment. That's why we use L·O·F Glass Fibers' Garan Roving. It has superior wetting-out characteristics, which give the boxes greater strength, and resistance to moisture and chemical agents. Garan Roving helps Toteline boxes last longer."

L·O·F Glass Fibers' exclusive Garanized® roving imparts great flexural and tensile strength to reinforced plastics. It bonds strongly and uniformly to polyester molding resin, both chemically and mechanically. Such plastics, reinforced with Garan roving, are stronger and have higher wet-strength retention. For numerous applications with epoxy, silicone, polyester resins, Vitron® VR-12 Roving is finding wide use among molders.

For technical counsel on how Garan Roving can improve your product, contact our nearest sales office, or write: L·O·F Glass Fibers Company, Dept. 37-115, 1810 Madison Ave., Toledo 1, Ohio.

LOF GLASS FIBERS Garan ROVING

L·O·F GLASS FIBERS COMPANY
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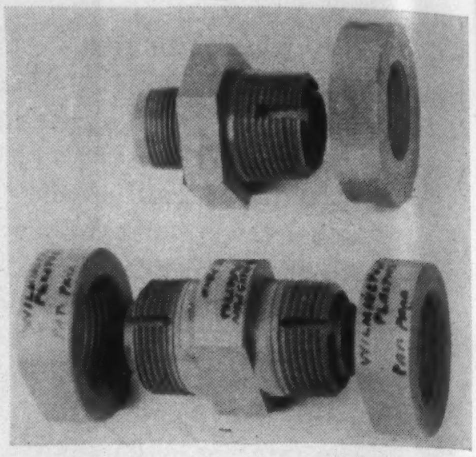
New Materials, Parts, Finishes



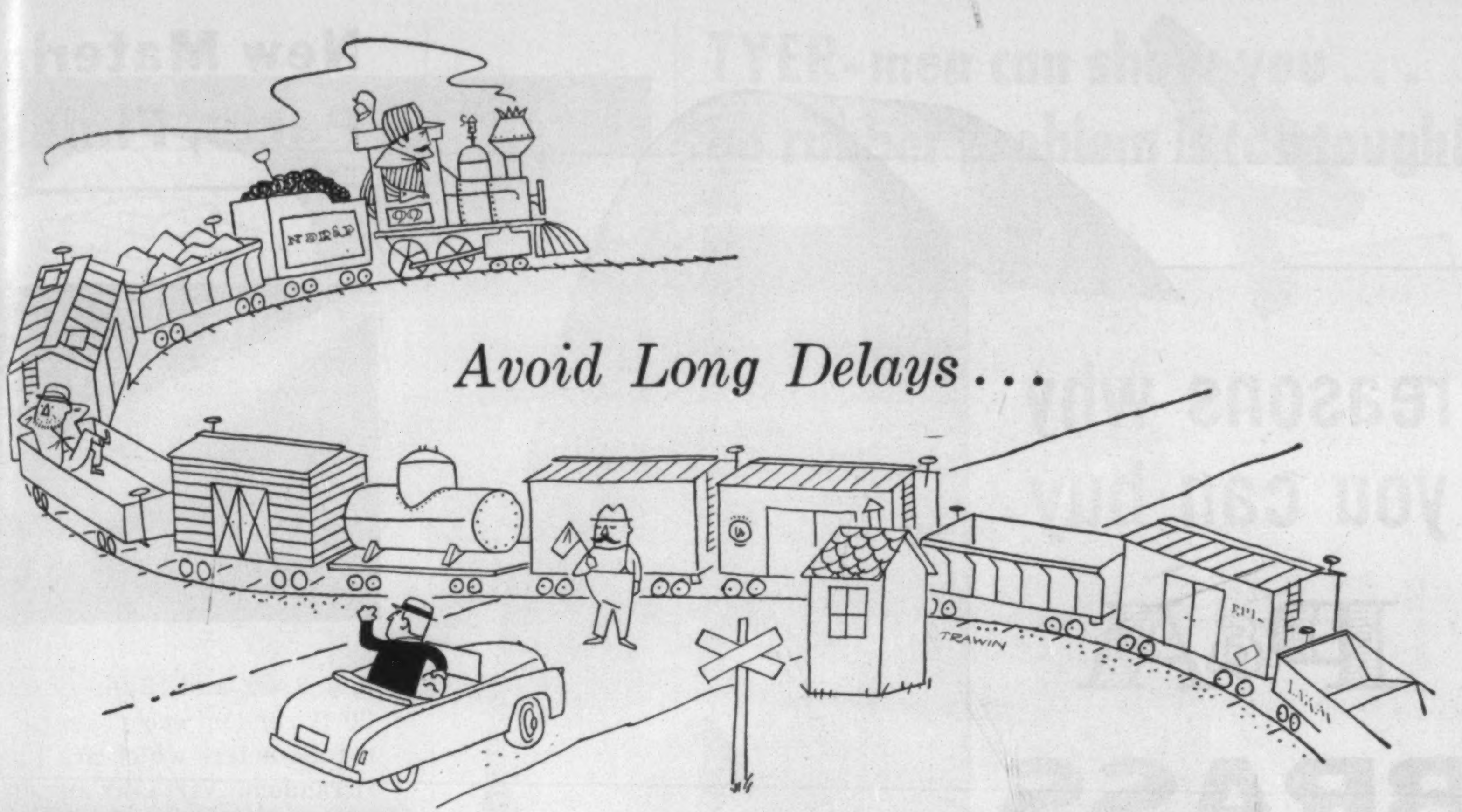
stresses in the polyethylene. They are presently available as polyethylene-to-polyethylene couplings and polyethylene-to-metal adapters, in ¾ and 1 in. sizes. Ultimately sizes will be increased up to and including 2 in. dia.

Vinyl tubing

A vinyl plastics tubing, Temflex 105, has been approved under government spec MIL-I-631B, and combines high dielectric strength, heat aging and fungus resistance. Produced by *Minnesota Mining and Mfg. Co.*, Irvington, N. J., the tubing is used by electrical and electronic equipment manufacturers, and is approved by Underwriters' Lab for continuous operation at 212 F. An improved formulation provides additional color stability and reduced shrinkage during sustained operation at elevated temperatures.

Glass-reinforced pipe

Glass fiber-reinforced plastics pipe, available with a range of resins, has been marketed by *Reinforced Laminates, Inc.*, 3040 E. Hennepin Ave., Minneapolis 13. It is designed primarily for use under corrosive conditions. Resins most commonly used are modified epoxies. Fabrication methods are such that the glass fiber reinforcement can be oriented to provide needed strength for different requirements. It can be used where moderately high pressures and temperatures are encountered. Pipe is now available with the following nominal i.d.: 1¾, 2, 2½, 3,



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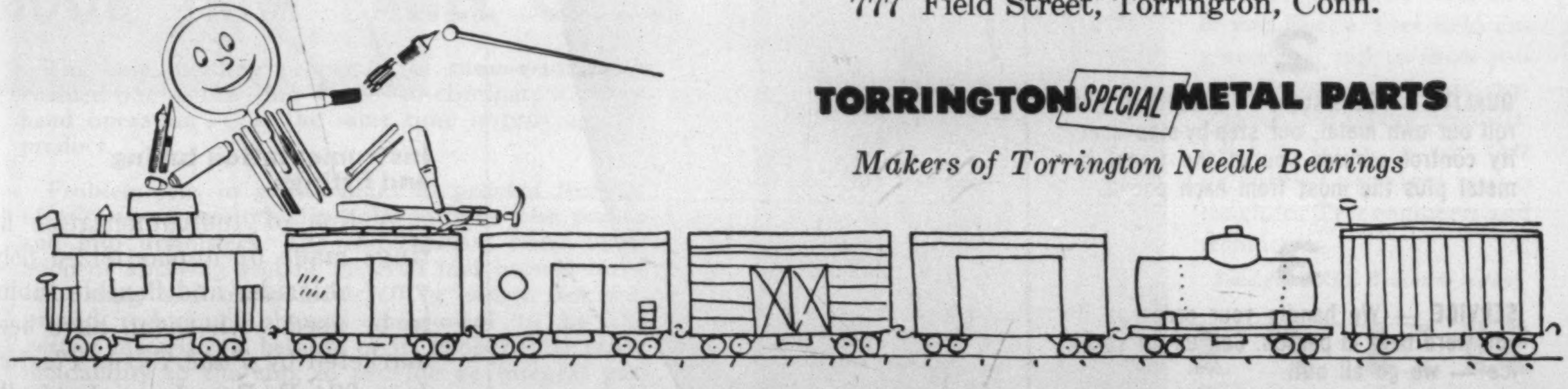

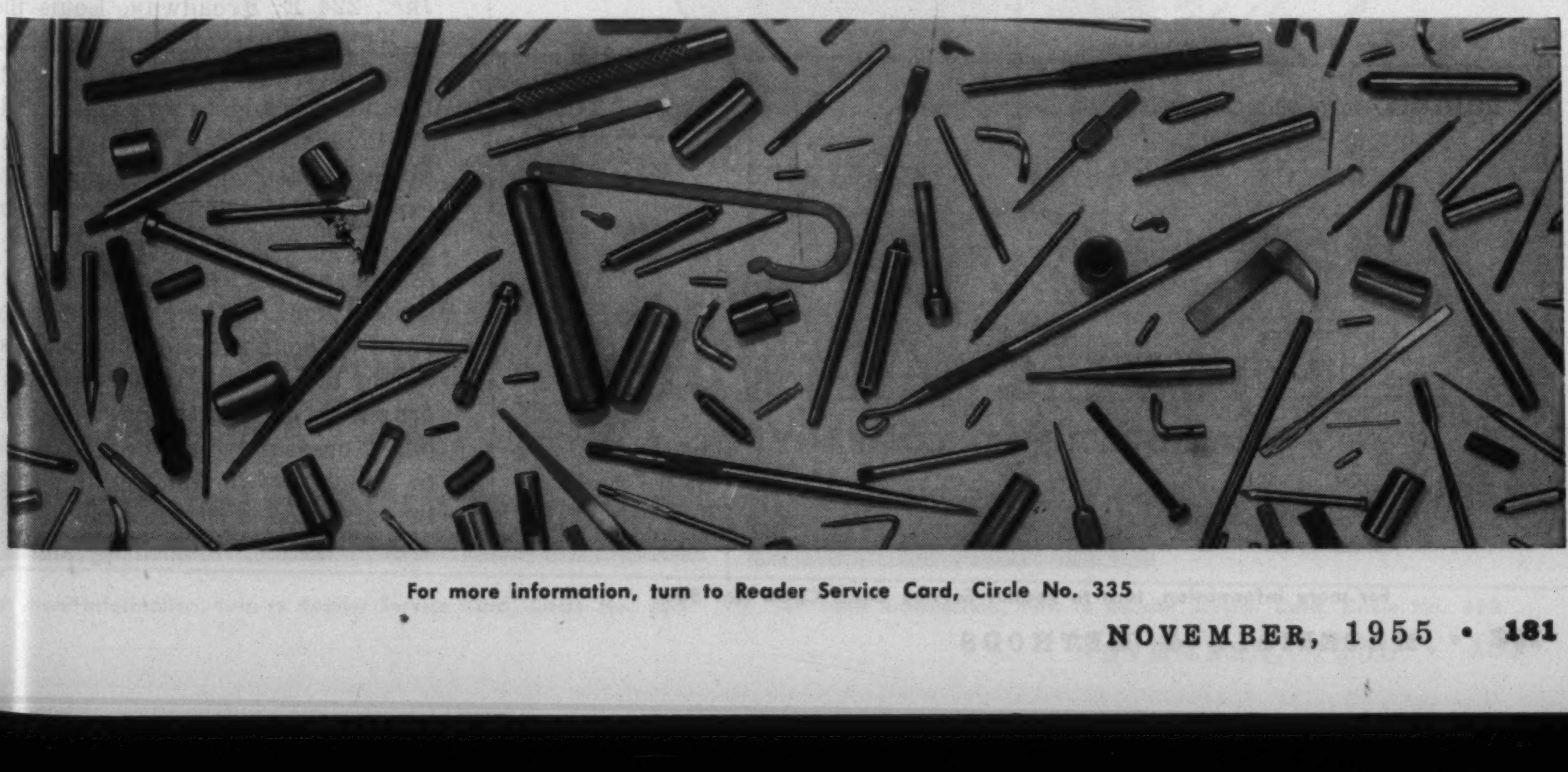

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4

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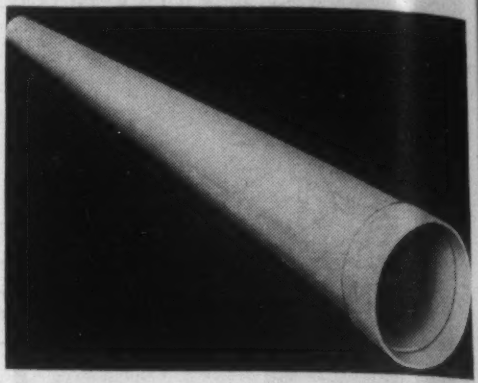
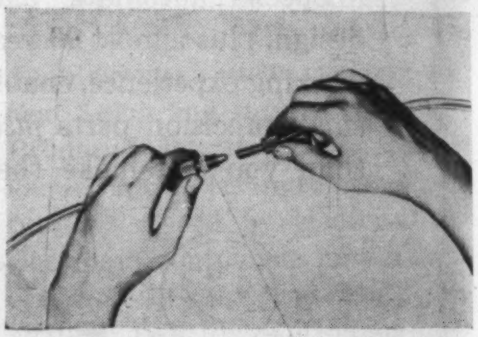
New Materials, Parts, Finishes

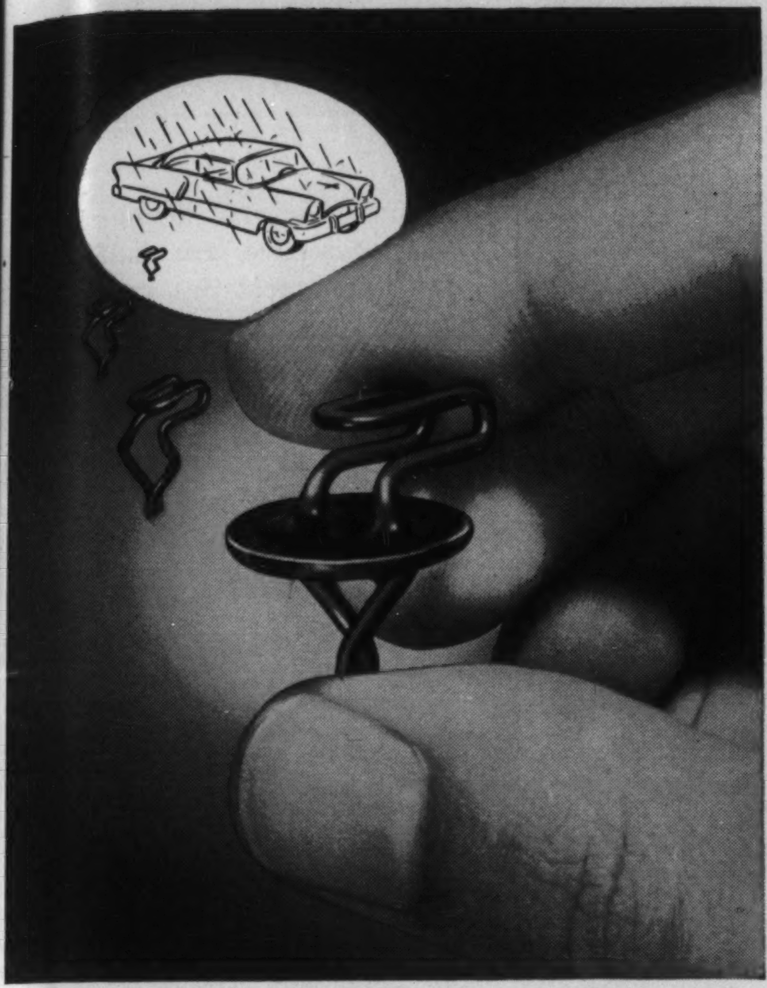


4, 6, 8, 10, and 12 in. Lengths are 20 ft random except on the smallest diameters which are 10 and 15 ft random. Virtually any diameter (up to 36 in.) and wall thickness could be supplied on a custom-built basis without excessive tooling costs. Couplings and other fittings of several types are available with standard sizes. Costs vary with construction requirements.



Instrumentation tubing and fittings

A line of instrumentation fittings made of unplasticized polyvinyl chloride, and flexible tubing to be used with them, have been marketed by *Tube Turns Plastics, Inc.*, 224 E. Broadway, Louisville 1, Ky. Because of their corrosion resistance, strength and low cost, the fittings and tubing can be advantageously used in instrumentation of chemical plants, hospitals, experimental laboratories, and in the food, drug and beverage processing industries. An entire assembly can be put together by hand without the aid of wrenches, flaring or bending tools, or stretchers. The PVC fittings will hold burst pressures in excess of those to which the flexible tubing may be subjected. Fittings and tubing are furnished in both ¼ and ⅜



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solves another problem by improving

DOOR TRIM PANEL CLIPS

The easy molding properties of **chem-o-sol** have enabled one of the "Big Three" to eliminate a costly hand operation — at the same time improving the product.

Problem was to gasket holes to prevent leakage of rain water through clip holes in door trim panels and into upholstery. The conventional hand operation of applying sealant material had proved time-consuming and unsatisfactory. The search for improved techniques showed **chem-o-sol** to be the perfect material — because of its property of ready moldability to the clip, to provide an integral gasketing unit.

This manageable liquid vinyl dispersion was especially formulated for production line application. Easily converted into a tough, flexible solid by controlled heat at moderate temperatures, **chem-o-sol** saved the manufacturer and customer time and money in this low cost molding operation.

Write to us for information on other applications of **chem-o-sol** by dipping, spraying, slush molding, and die wiping. Learn how our individual formulations of **chem-o-sol** have improved other products — created new ones.

Information courtesy of Mattatuck Mfg. Co., Waterbury, Conn.

Send for Bulletin 141.

Chemical Products CORPORATION
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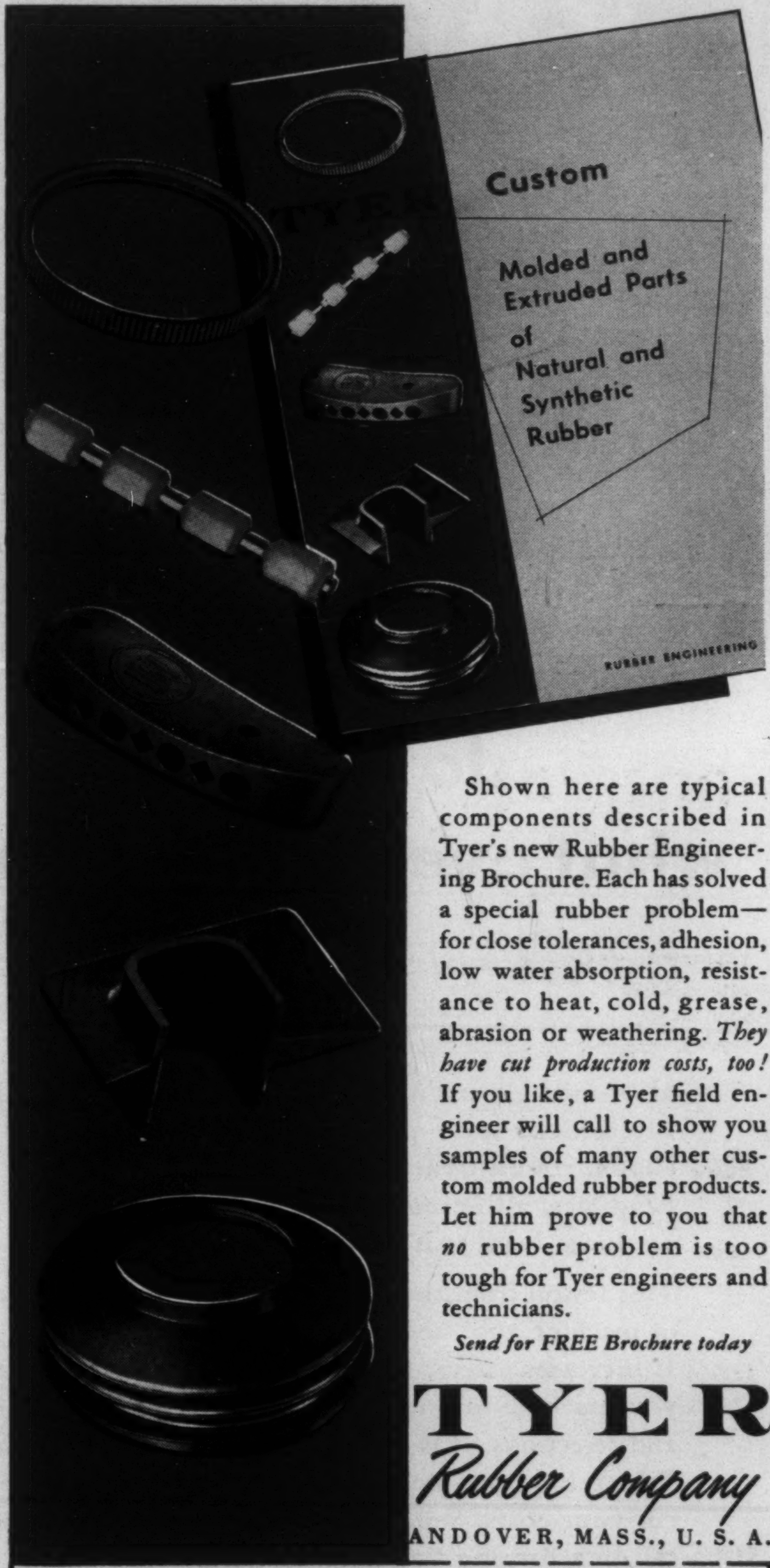
TYER-men can show you . . .
no rubber problem is too tough!



Shown here are typical components described in Tyer's new Rubber Engineering Brochure. Each has solved a special rubber problem—for close tolerances, adhesion, low water absorption, resistance to heat, cold, grease, abrasion or weathering. *They have cut production costs, too!* If you like, a Tyer field engineer will call to show you samples of many other custom molded rubber products. Let him prove to you that *no* rubber problem is too tough for Tyer engineers and technicians.

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☐ Please send me the new *Tyer Rubber Engineering Brochure* including technical specifications and relative properties of natural and synthetic rubbers.
☐ Please have Tyer field engineer call on________ (date)
No obligation, of course.
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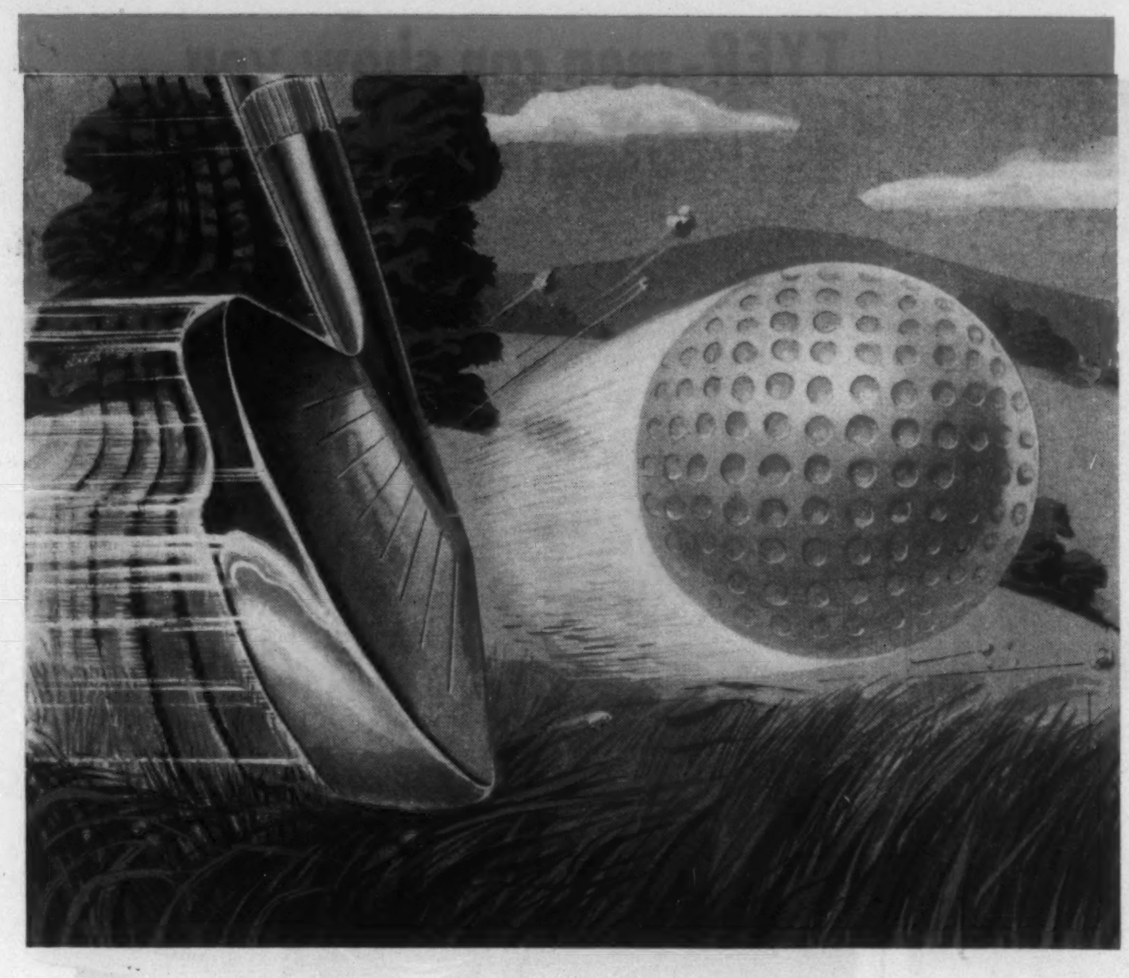

do you apply what every golfer knows?

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With a *crack* the iron sends the ball winging toward the pin at an initial speed up to 250 ft. per second (170 MPH!), and often kicks some pebbles along with the ball, too. That's shock, rough treatment for metal. But a *forged* golf club head lasts a lifetime. The dense metal is free from internal weakness because it is closed-die forged.

This lesson from the golf club applies to parts for every kind of machine, tool, and equipment. You can trust forged metal. It increases safety. Because the metal is internally sound as you machine into it, it cuts costs for machining, inspection, and rejections. It is uniform to withstand shock and fatigue. Take full advantage of forgings to improve your product, to cut your costs. Send for the booklets described below, and call in a Forging Engineer, to learn what forgings offer you.

closed-die forgings for metal you can trust

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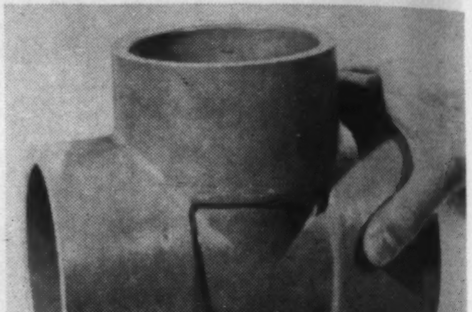
Attach this advertisement signature to your letterhead and mail to Drop Forging Association to receive booklet "What is a Forging?" ☐ or "Management Guide to Use of Forgings". ☐ Check title or titles desired.

For more information, turn to Reader Service Card, Circle No. 321

in. sizes. Types of fittings immediately available are half unions, for joining plastics to male pipe threads; unions and bulkhead unions for joining plastics to plastics; connectors for joining plastics to female pipe thread; and caps. Maximum working pressure is 150 psi at 75 F.



Large PVC fittings

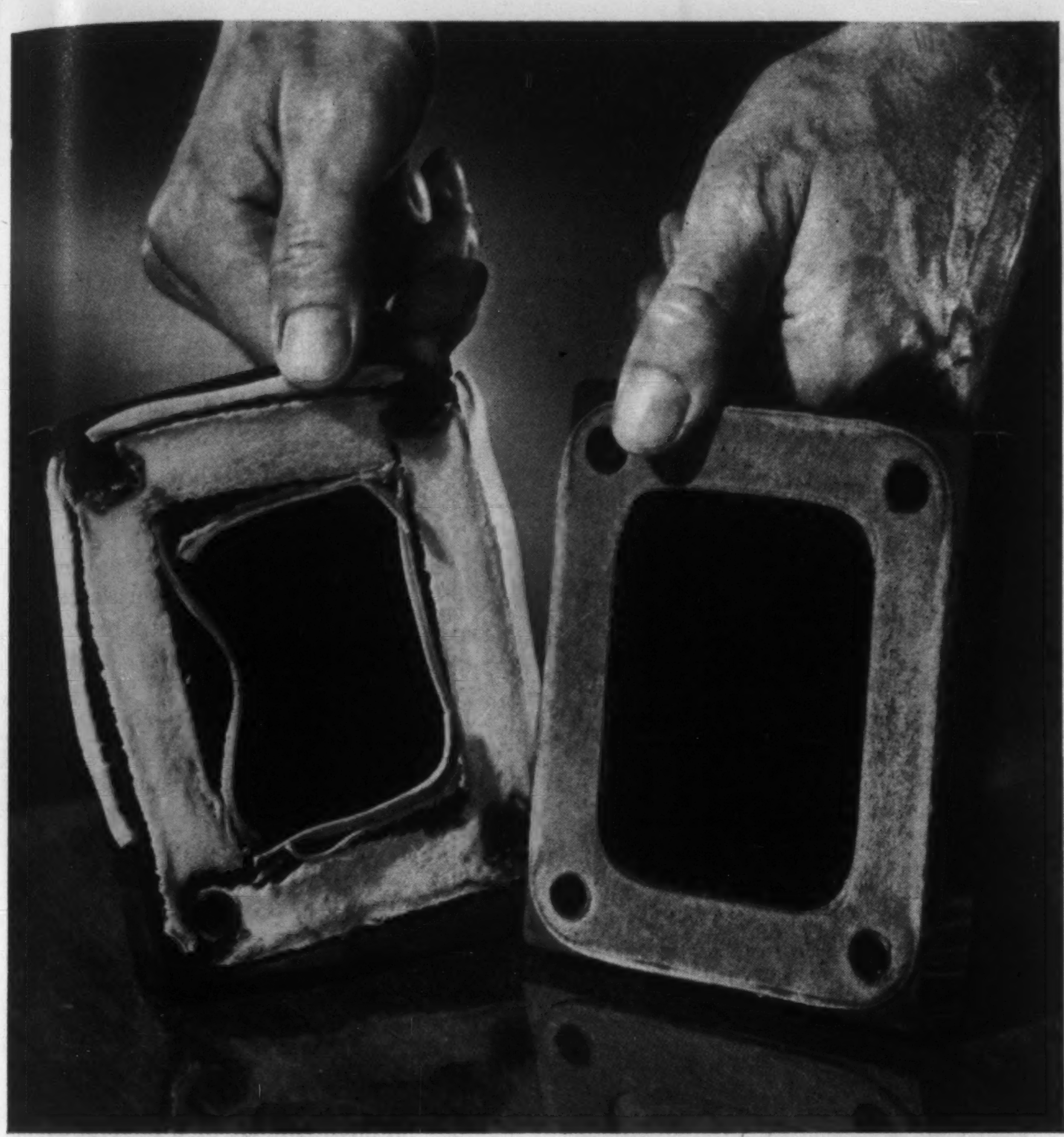
Unplasticized polyvinyl chloride fittings for 3 and 4 in. pipe are now being injection molded by *Tube Turns Plastics, Inc.*, 224 E. Broadway, Louisville 1, Ky. Included are 90 and 45 deg. elbows, tees, couplings and flanges. The fittings are available in normal and high impact PVC and in threaded and socket types, the latter designed for attachment to pipe by solvent or fillet welding.

New Tapes

Two new tapes have recently been marketed to serve several purposes. They are: 1) aluminum foil tape for electrical work; and 2) two 2-mil polyester (Mylar) tapes for electrical work.

Aluminum foil

A pressure-sensitive aluminum foil tape designed for use as a moisture vapor barrier in communication cable splices has been developed by *Minnesota Mining and Mfg. Co.*, Dept. E5-252, 900 Fauquier St., St. Paul 6. Called Scotch brand electrical tape No. 49, it has been approved for use in REA cable splicing specifications



Cold flow resistance of TEFLON* and reinforced TEFLON (DUROID 5600) was tested at 700° F., under a torque of 35 pounds and a flange pressure of 1,000 p.s.i. After 2 hours the flanges were cooled and the bolts retightened. The flanges were then exposed to the heat for another 2 hours. Results are as pictured. The gasket of TEFLON (left) extruded extensively on all edges and lost all bolt torque. DUROID 5600 did not extrude and retained 15 pounds bolt torque, demonstrating significantly improved resistance to cold flow.

Greater Resistance to Heat Distortion

TEFLON (left) distorted badly when subjected to 720° F. and then cooled. Reinforced TEFLON (DUROID 5600) exposed simultaneously to the same temperature retained flatness, demonstrating greater dimensional stability at high temperatures.

SOME IMPORTANT TEST VALUES

Tensile Strength, MD, psi	2500
Tensile Strength, CMD, psi	1500
Compressibility, 5000 psi, %	8
Thermal Expansion Coefficient per °F., 73-140°F.	2.7 x 10^{-5}
Heat Distortion Temperature, °F.	
66 psi	500+
264 psi	500+
Deformation under Load, %	
1200 psi	2*
2000 psi	3*
Coefficient of friction against polished steel,	
static	.21
kinetic	.14
Specific Gravity	1.90

*Made up of actual flow and also of compression under load. Data to indicate breakdown between these two portions is being obtained.

ROGERS REINFORCES "TEFLON" TO REDUCE ITS COLD FLOW

Rogers DUROID 5600 is a combination of TEFLON and inert fibers, blended into an homogeneous sheet material. This new material is not a replacement or a substitute for TEFLON, but rather an extension of it. TEFLON has better electrical characteristics and dry lubricating qualities. DUROID 5600, however, has much of TEFLON'S resistance to chemicals, and is greatly superior to TEFLON in resistance to cold flow and heat distortion.

Please write

Dept. M

for Technical Bulletin

*Registered trademark of DuPont Company for its tetrafluoroethylene resin.

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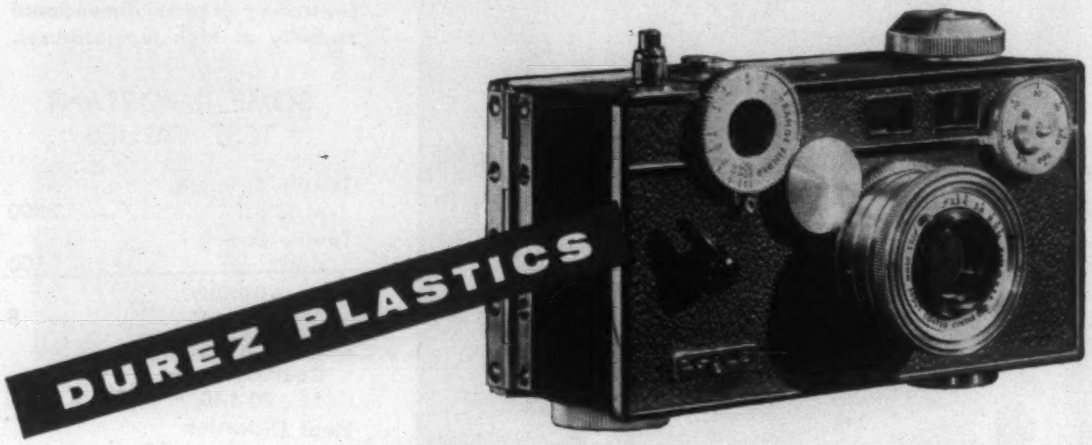
THE DUAL ROLE OF

DUREZ IN INDUSTRY



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PC-2 and PC-3. The tape has a 3-mil dead soft foil backing with a tensile strength of 33 lb per in. of width. Total thickness including adhesive is 5 mils and strength of adhesion is 25 oz per in. width. It is recommended for use in taping plastics insulated-plastics sheathed cable splices and also where such cable is spliced to conventional paper insulated-lead sheathed telephone cable. It is available in 2-in. wide, 20 ft long rolls.

Polyester film

Two 2-mil Mylar film, Electrical Heat Curing Tapes are being marketed by *Permacel Tape Corp.*, New Brunswick, N. J. Designated Permacel 254 and 255, the tapes have good adhesive characteristics in the uncured state. After curing with heat, the adhesive becomes firm with increased holding power and good solvent resistance. The tapes, one clear, the other a vivid yellow, consist of 2 mils of Mylar backing and a rubber-base adhesive, which is free of corrosive agents and contains no sulfur. The tapes have a tensile strength of 50 lb per in. of width, elongation of 100%, and adhesion to steel of 40 oz per in. of width, and require a minimum curing cycle of 2 hr at 250 F or 1 hr at 300 F. When cured, both are resistant to varnish and paint solvents. They both have low moisture vapor permeability and will withstand temperatures up to 300 F.

Recommended applications include banding field and armature coils and holding down lead wires in electric motor and generator manufacturing, for holding down start and finish wires, securing leads and insulating cores and providing an outside wrap which is resistant to moisture, abrasion and chemicals. Both are also used in Class B insulated electronic components and electrical units where longer life is desired.

Contents Noted

A digest of papers, articles,
reports and books of current interest
to those in the materials field.

This Month:

- *Cold rubber*
- *Zinc after 20 years*
- *Water-base coatings*
- *Through vs case hardening*
- *Repairing fatigue damage*

Natural Rubber for Low Temperature Service

Demands are increasing for rubber materials that will remain flexible at low temperatures. In the rash of developments of synthetic elastomers, sight should not be lost of natural rubber. According to experimental work at the British Rubber Producer's Research Association, natural rubber has a lower stiffening temperature than any of the standard production organic elastomers. Of course its low temperature flexibility is surpassed by that of silicone rubber and by so-called arctic GR-S (XPRD70, Polymer Corp.).

Natural rubber is practically equivalent in low temperature stiffening to 85-15 butadiene styrene polymer and 80-8-12 butadiene isoprene styrene polymer, both of which, however, show inferior physical properties. These conclusions are contained in an article by W. P. Fletcher of the BRPRA in the August issue of *Revue Generale du Caoutchouc* (French). Comparative low temperature properties of rubbers are shown in Table 1.

Modifications

Fletcher goes on to say that work at the Association has shown that several readily available plasticizers, such as di-iso-octyl sebacata and di-iso-octyl adipate, can provide compounds with satisfactory low temperature flexibility. Two compositions are shown in Table 2 compared with properties of two plasticized synthetic rubbers. In the table, the two natural compounds are: Compound C, providing a 46 F improvement, and Compound G, which will remain flexible 72 F below an unplasticized rubber. Data indicates that at a very low fixed temperature, flexibility may be retained with less sacrifice of strength by using a plasticized natural rubber composition than with a plasticized GR-S or a plasticized low styrene-butadiene copolymer.

Crystallization

When a vulcanized natural rubber is subjected to temperatures of 32 to −40 F over a long period of time, stiffening and loss of elasticity may take place. This is due to crystallization, and can render a product unsuitable for use. Stiffening by a factor of 25 or more has been encountered as crystallization proceeds. Another effect of crystallization is the relaxation of stress in a strained rubber maintained at low temperatures. Complete loss of stress results if sufficient time is allowed. Crystallization of natural rubber, either raw or vulcanized, proceeds at a maximum rate at about −15 F. The rate is enormously affected by strain, e.g., rate is increased

1—PHYSICAL AND LOW TEMPERATURE PROPERTIES OF RUBBER
(data of Helin and Labbe)

Polymer	NR	GR-S	BD^2 XP-148	BD^2 XP-169	BD^2 81PC4-6	Na^1 BD/S^2 75/25	XP138 BD/S^2 85/15	BD/I/S^2 80/8/12
$^3T_{10}$ F	—60	—44	—90	—45	—38	—4	—69	—69
Ten Str, psi	4280	3180	1430	2190	1580	2390	1790	2330
Mod at 300% elong, psi	1090	840	950	1390	570	990	1090	1600
Elong at break, %	640	660	390	390	540	540	410	380

[1] *Na indicates sodium catalyzed polymerization.*
[2] *BD = Butadiene, S = Styrene, I = Isoprene.*
[3] *T_{10} = temperature for 10-fold modulus increase (Gehman test).*

2—PHYSICAL AND LOW TEMPERATURE PROPERTIES
OF PLASTICIZED NATURAL AND SYNTHETIC RUBBER COMPOUNDS

Compound Type	Compound C (NR)	Compound G (NR)	GR-S	XP-138 BD/S 85/15
Ten Str, psi	2430	1720	1560	1750
Mod at 300% elong, psi	1680	585	940	1100
Elong at Break, %	448	545	430	420
Hardness, Shore	63	56	40.5	44.5
T_{10} F	—78	—108	—75	—79

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Contents Noted

approximately tenfold on 100% elongation and a hundredfold on 200% elongation, compared with that shown by unstrained rubber.

Natural rubber crystallizes much more readily than GR-S, which contains 25% styrene. Polybutadiene, as long as it is relatively unbranched, is an easily crystallizable polymer with a very low glassy transition temperature, and many butadiene-styrene copolymers with styrene contents between 5 and 20% have been made in attempts to combine the low glass transition temperature with the non-crystallizing character of GR-S. A styrene content of 15-18% has been reported as the minimum necessary to provide minimum satisfactory resistance to crystallization in copolymers made at 40 F.

The future

The different uses of rubber require different degrees of resistance to crystallization, and possibly the maximum resistance obtainable by various accelerator systems may be inadequate for certain stringent conditions of service. Recent work has shown that slight chemical modification of the rubber molecule prior to vulcanization provides a further retardation of crystallization by a factor of 50 to 100 over that given by the best choice of vulcanizing system. Details of this process, still under development, will be published later.

Twenty-Year Corrosion of Zinc

Useful data have just been compiled summarizing a 20-yr exposure program set up to investigate atmospheric corrosion of rolled zinc. Corrosion was found to be controlled by three principal factors: 1) frequency of rain and dew fall; 2) acidity of moisture; and 3) rate of drying. Corrosion rate is a maximum in industrial locations which combine acidic atmosphere with heavy mists and dew. The program was initiated in 1931 by Committee B-3 of the American Society for Testing Materials. E. A. Anderson of New Jersey Zinc summarized results of the program in a paper delivered before the ASTM last June.

Conclusions drawn

Weight change determination was found to be the most satisfactory method of providing valid data. Though tension testing of specimens cut from corroded plates was found to be valuable as a procedure, no satisfactory method of correction for aging changes in the metal has been found.

The accompanying table shows average penetration over the twenty year test period for the four types of atmospheres in which tests were carried out. Three slab zinc grades were tested, Prime Western, High Grade and Special High Grade. No significant relation was found betwen zinc composition and corrosion rate. Corrosion rate of zinc is lowest in dry, pure atmospheres and highest in industrial atmospheres. Seacoast atmospheres not in direct contact with salt spray

CORROSION OF ZINC

Type Atmosphere	Average Penetration, mils per yr	Ratio of Penetration, in relation to that at Phoenix
Industrial	0.252	36
Seacoast	0.058	8.3
Rural	0.042	6
Arid (Phoenix)	0.007	1

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Even more helpful in many uses is its glass-like clearness which permits full solution visibility and control. Polished surfaces give maximum flow, lengthen intervals between cleaning. And nontoxic formulations of Tygon are approved by leading medical authorities and Boards of Health for transmission of food products.

Write today for a copy of Bulletin T-87. Its 24 pages of technical data may point out a more effective, lower cost way of piping your products. 185-E

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Plastics and Synthetics Division

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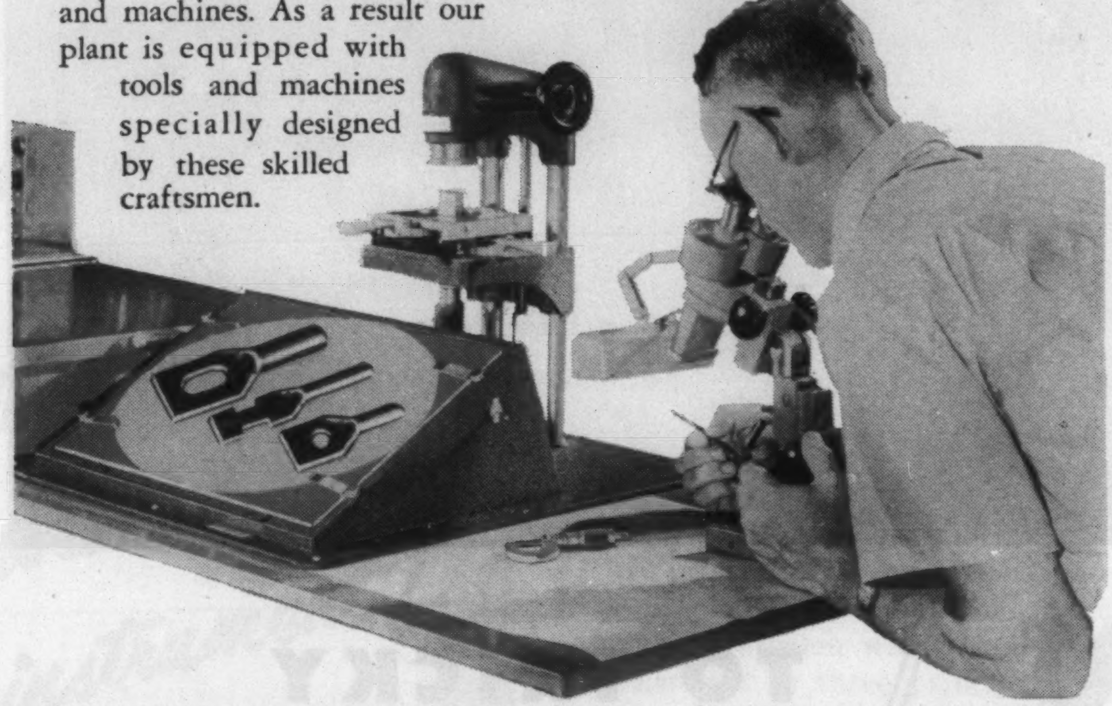
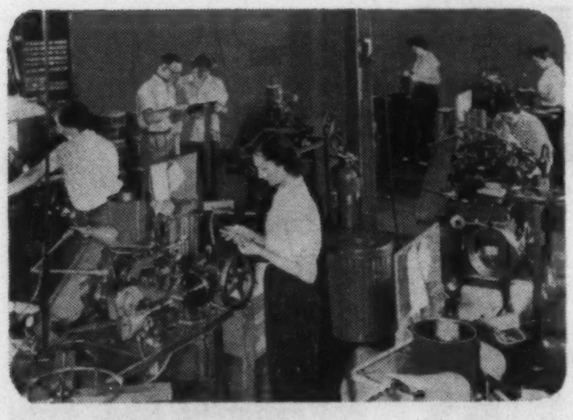
Seamless tubing parts cut, flared, flanged or bulged to exacting engineering specifications, require special handling all the way down the line for highest results. All our personnel take a special interest in every order received in this plant—to see that our product never falls short of the customers' standard.

We believe our highly skilled personnel are worthy of the finest tools and machines. As a result our plant is equipped with tools and machines specially designed by these skilled craftsmen.





Kleiner seamless tubing parts retain uniform wall thickness—are cut with square ends, and vary from no burr to a maximum of one thousandths of an inch. Our continuous quality control checks these and other factors to insure parts that meet our customers' every requirement.

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For more information, turn to Reader Service Card, Circle N[illegible] 307

Contents Noted

are mildly corrosive to zinc. The essential difference between the arid and rural environments lies in the moisture present in the latter as humidity, rainfall, and most important, dewfall. The moisture produces a six-fold increase in the rate of zinc as compared with arid locations.

Corrosion mechanism

Four characteristics of the metal itself were found to control atmospheric corrosion of zinc. They are: 1) Zinc is attacked by acids at rates which decrease as pH increases; 2) zinc is capable of forming insoluble basic salts when appropriate pH levels are reached; 3) zinc has a high hydrogen overvoltage; and 4) zinc is electronegative to its metal impurities, to hydrogen, and to most surface contaminants.

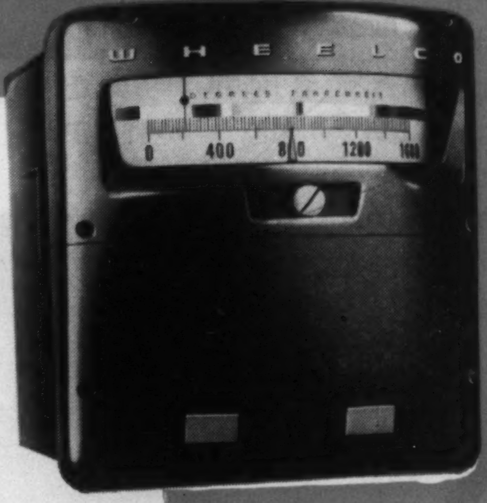
In pure atmospheres contact with rain, mist or dew results in formation of zinc hydroxide with the release of hydrogen. The zinc hydroxide layer then reacts with carbon dioxode dissolved in the water to form an insoluble basic zinc carbonate. Zinc's high hydrogen overvoltage tends to stifle corrosion by permitting formation of an interfering hydrogen film. Since the thin water films are highly aerated and oxygen can diffuse rapidly to the metal surface, removal of these hydrogen films by oxidation can take place rapidly.

Accordingly, the rate of corrosion in purer atmospheres should depend on frequency and duration of moisture contact, and this has been found to be the case in many instances.

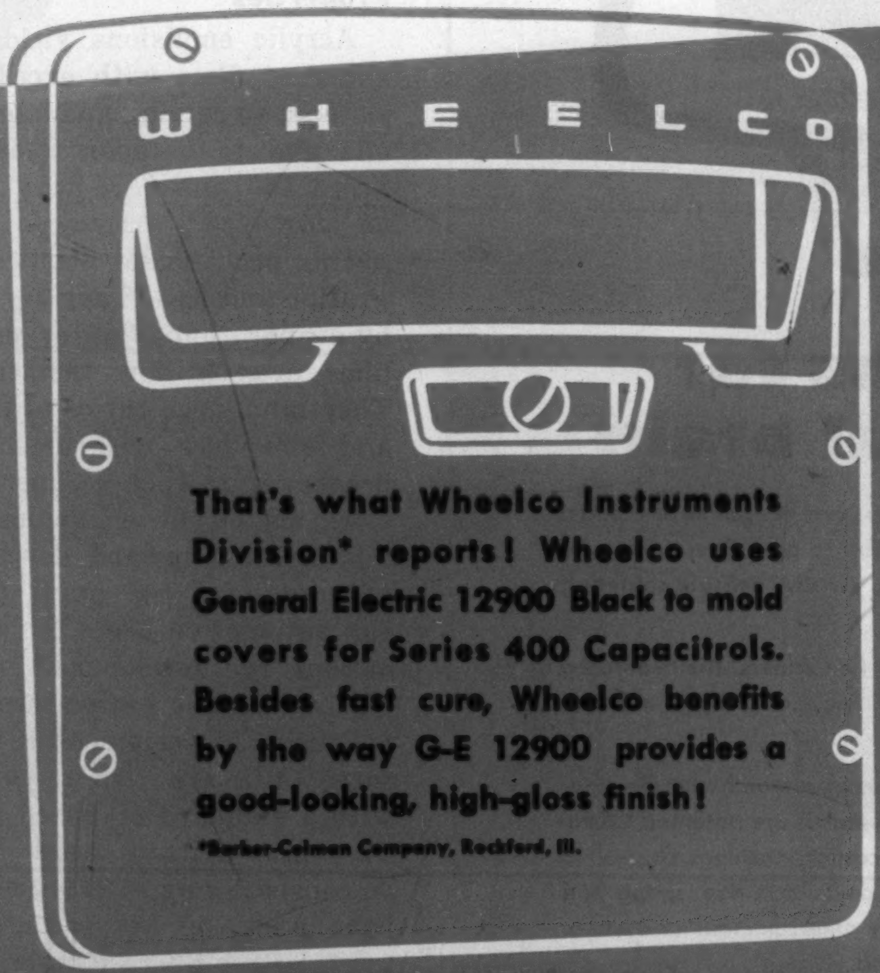
Water-Base Industrial Finishes

Water-based industrial coatings have several desirable features which have sparked recent interest in their development. They are non-flammable; water is cheap, readily available and odor free; and there is no need for expensive solvent recovery system and no

"FAST CURE... even with heavy sections"



...through G.E.'s new 12900 Black general-purpose phenolic molding compound



That's what Wheelco Instruments Division* reports! Wheelco uses General Electric 12900 Black to mold covers for Series 400 Capacitrols. Besides fast cure, Wheelco benefits by the way G-E 12900 provides a good-looking, high-gloss finish!

*Barber-Colman Company, Rockford, Ill.

General Electric's new 12900 Black and 12901 Brown are among the fastest-curing and most versatile phenolic materials on the market today. Suitable for cold powder as well as preheat applications, these high-density powders result in uniform pill weight, fast cures, and rigid set. Where can *you* use them to increase output, lower production costs and mold high-quality, attractive plastic parts?

For more information on G-E general-purpose molding compounds, just write to General Electric Company, Section 520-4B, Chemical Materials Department, Pittsfield, Mass.

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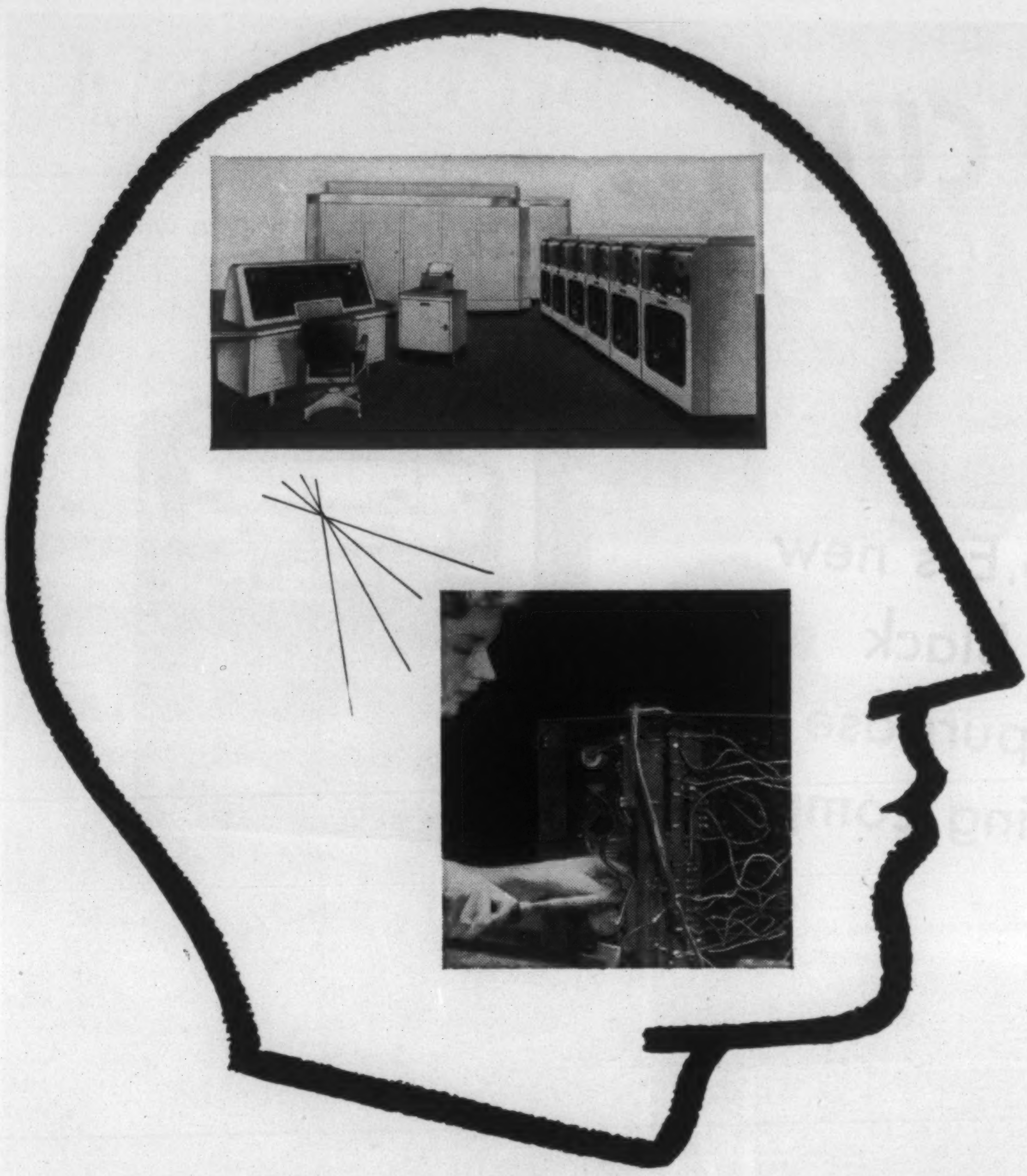

Metal ganglions for the mechanical brain

The nerve centers of modern electronic computers are the points of contact that permit the flow of electrical current from part to part. These points of contact must be firmly and permanently joined. Usually, delicate soldering operations are used for this purpose.

The electronics industry requires many tons of fine solders. The Federated Metals Division of American Smelting and Refining Company is a major producer of these solders.

Federated solders are the result of many years of research and development. Typical of advances made by Federated research are patented Castomatic bar and ingot solders. Made on automatic casting machines, controlled by electronic instruments, each bar or ingot is identical in size, shape and weight, with uniform composition unequalled by other methods of casting. Every bar gives the same results in the user's hand.

No matter what size, shape or composition you may need in a solder, think of Federated first as a source of supply. Our broad experience with all kinds of non-ferrous metals has earned us the name of Headquarters for Non-Ferrous Metals.

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noxious fumes to be controlled. Furthermore, particularly in the automotive industry, wet sanding with water is commonplace and paints that would adhere to damp surfaces would permit faster production and eliminate one drying step.

There are at least three types of systems that have been studied: heat hardening phenolic systems, alkyd-nitrogen resin emulsion system and the acrylic emulsion system. Rohm & Haas's work on acrylic emulsion systems is summarized in a paper by G. Allyn presented before the Technical Sub-Committee, National Industrial Product Finishes Div., of the National Paint, Varnish & Lacquer Assoc. last September.

Properties

Acrylic emulsions yield tough, adherent films with excellent resistance to cutting and lubricating oils and to outdoor weathering. Since the films are very flexible no plasticizers are needed, eliminating problems of plasticizer migration and loss. They dry quickly by evaporation of water and form films even at low temperatures. They bind large ratios of pigment and extenders without emulsion breakage. Much experimental work on acrylic emulsions is being directed toward development of successful red oxide primers for automotive use. At present, outlook for development of gloss topcoats is not too encouraging.

During developmental testing, three primers were compared with a standard oil-based primer. The three primers were: Primer A, consisting of 70% pigment (40 iron oxide, 40 barytes and 20% talc), 30% binder; Primer B, consisting of 70% pigment (40 iron oxide, 40 barytes and 20% acicular zinc oxide), 30% binder; and Primer C, consisting of 60% pigment (50 iron oxide and 50% barytes), 40% binder. An alkyd-melamine baking enamel was used as topcoat.

Test results

Panels were wet sanded with No. 400 paper, the higher pig-

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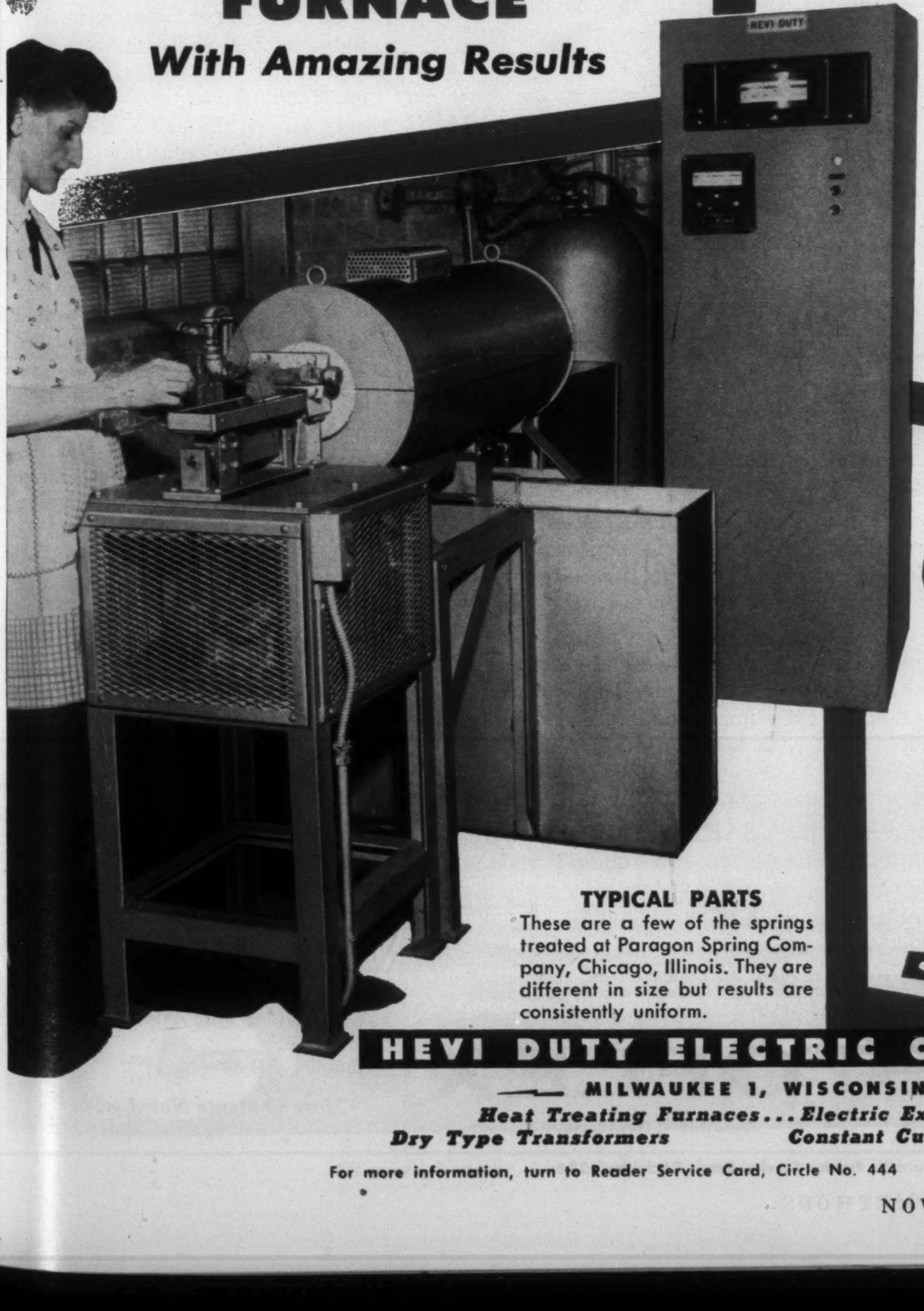
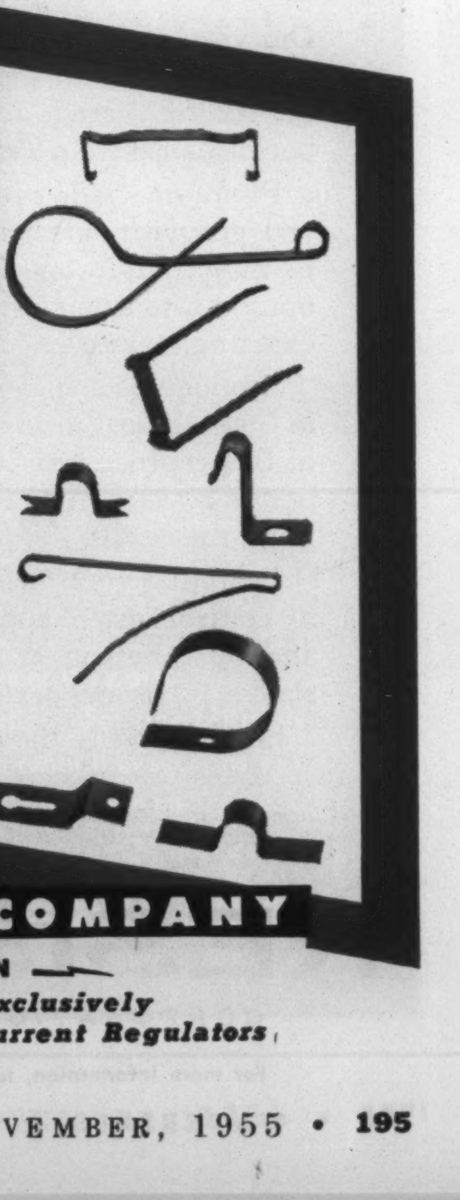
Here's what Ed. Stanek says . . .

Ed. Stanek, Heat Treating Superintendent says, "We sure were amazed at the improved quality of our springs. With our new Hevi Duty Shaker Hearth Furnace, we get clean scale-free parts that do not require pickling or sandblasting before plating. In addition to that, we get a better, cleaner plating job than before. The parts retain their carbon and are less subject to hydrogen embrittlement. Now, heat treating takes less time and rejections have been practically eliminated. Our customers are really getting fine quality springs."



UNIFORM CASE DEPTH
This Hevi Duty Shaker Hearth Furnace is fully adjustable to give complete control of heat treating processes such as Hardening, Dry Cyaniding and Carburizing. Write for Bulletin HD-850 describing the furnace that assures uniform results on a production basis.

TYPICAL PARTS
These are a few of the springs treated at Paragon Spring Company, Chicago, Illinois. They are different in size but results are consistently uniform.



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ment ratios giving somewhat better sanding properties. Formulation A with 20% talc produced excellent sanding properties. Tests for enamel hold-out and gloss were carried out with a blue automotive enamel and measuring 60-deg gloss. Differences were slight and not very significant. All three primers and the standard primer showed excellent hold-out. All of the acrylic primers were somewhat softer than the standard control primer, which may mean they will provide better adhesion and impact resistance.

All the acrylic primers showed good salt spray resistance. The films, either alone or topcoated, and using a scored panel, withstood 500 hr of salt spray with only slight blistering and undercutting. Undercutting at the scratch marks with topcoated acrylic primers occurred between topcoat and primer, while the commercial primer undercut at the metal.

Formulation B gave best results in water immersion resistance. Zinc oxide seems essential in these systems if good resistance is to be obtained. None of the acrylic primers showed rusting, but rust was visible on the commercial control system. In cold testing, Primer B, which looked so good in salt spray resistance, did not resist freezing. Formulation A withstood five freeze-thaw cycles with only slight flocculation.

Suggested formulation

Based on the results obtained in these studies, Allyn recommends a formulation which should form the basis for further study. He points out that more work remains to be done; however, the following formulation seems to be the optimum to work from.

Pigment (65%)	
Iron oxide	40%
Barytes	40%
Acicular zinc oxide	10%
Talc	10%
Rhoplex AC-33 (35%)	

(More Contents Noted on p. 198)

C	Mn	Pmax	Smax	Si	Cr	Mo
0.28/0.33	0.40/0.60	0.040	0.040	0.20/0.35	0.80/1.10	0.15/0.25

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4100 steels are your best bet

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CLIMAX MOLYBDENUM

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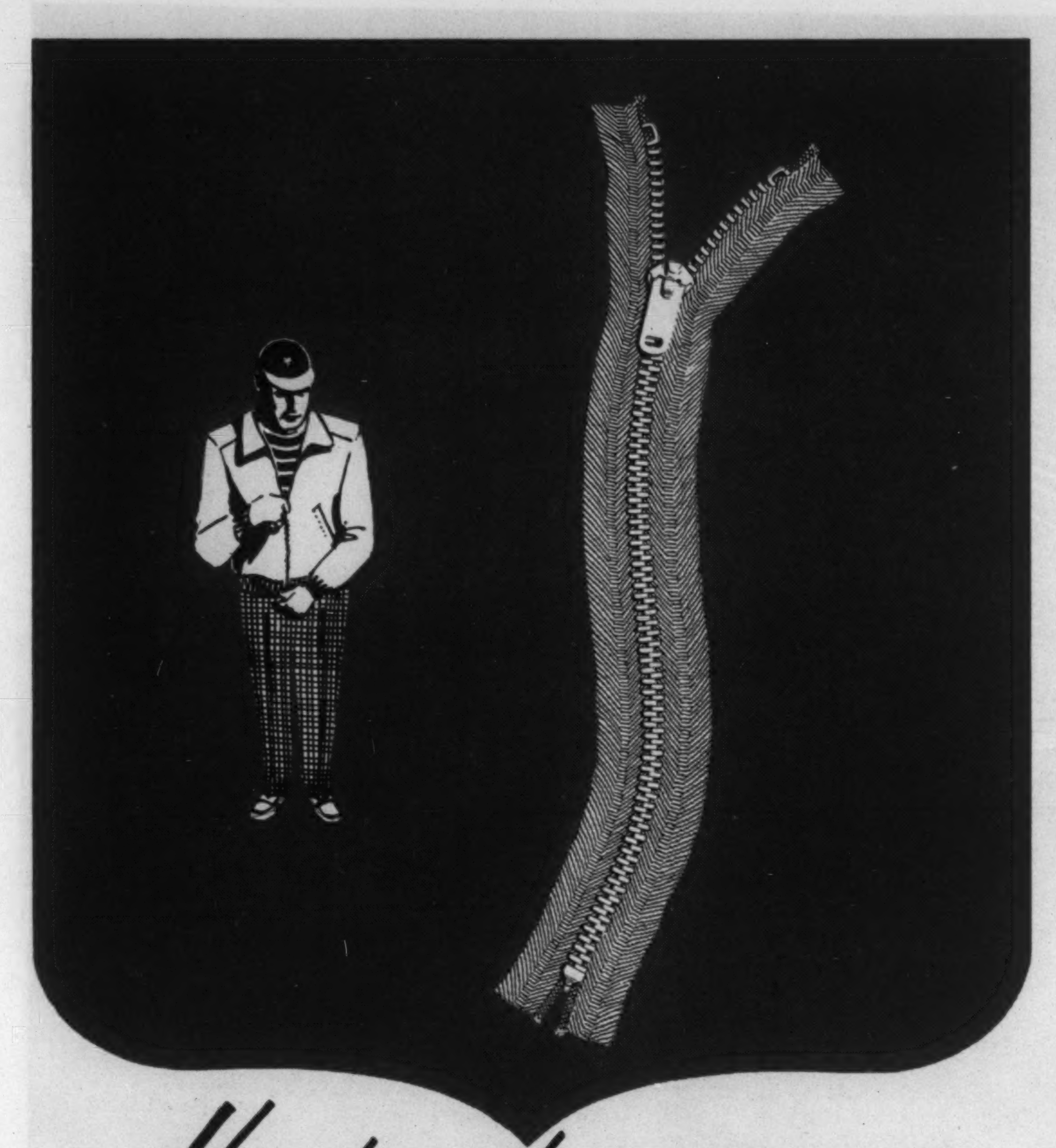

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But regardless of what nickel silver alloy your product may be made, for the best results the alloy you use must be a combination of the right composition and the right properties.

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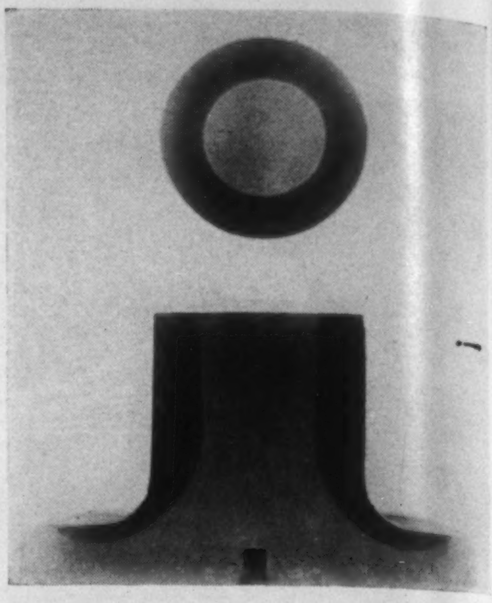


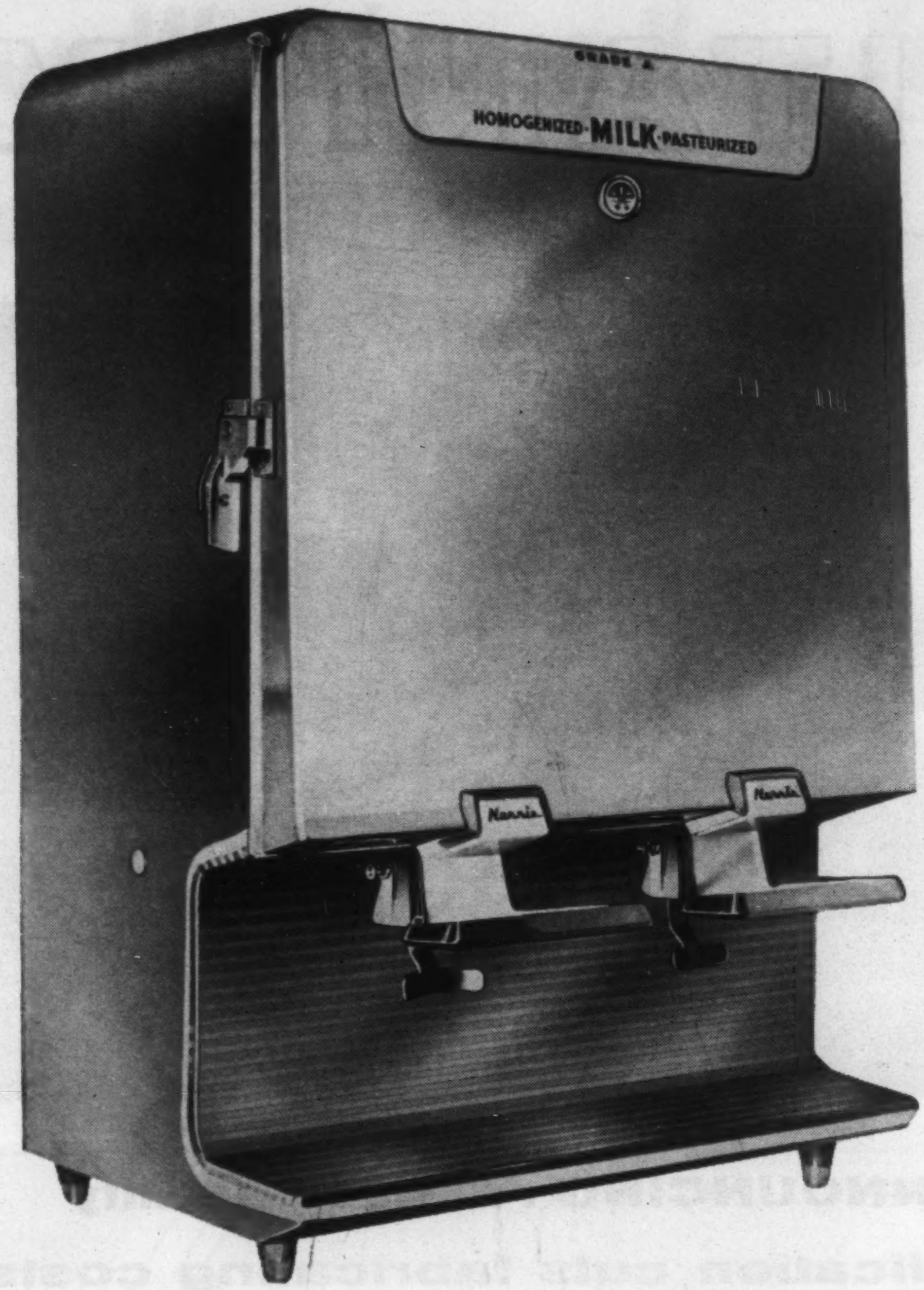
Contour of hardness pattern *of induction hardened core treated axle shaft.*

Truck Axle Strengthened by Induction Hardening

The ever-increasing loads being undertaken by trucks, power shovels and other automotive machinery have made axle shafts more prone to fatigue failure. A recent change in hardening techniques by the Axle Div. of Eaton Mfg. Co. has provided a sixfold improvement in fatigue life of truck axle shafts. In effect, Eaton changed from through-hardening to case hardening by induction heating. Though car manufacturers have used induction heating for hardening auto axle shafts for several years, hardening of truck axles is more complex in that the flange fillet must be hardened also. T. A. Frischman, of Eaton's Axle Div., described results of the change in an article in the September issue of *Eaton Engineering Forum.*

The problem

Spline roots and axle body were the two principal points of failure in shafts. In spline-type failures, fracture progressed from the root fillet inward to the center of the shaft, resulting in eventual breaking or twisting off of the shaft. In body fatigue, failure originated as minute longitudinal cracks progressing inward faster than lengthwise. The obvious so-



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Cleanability, product protection and bright good looks are the main reasons Norris insists on stainless steel. But stainless offers many other properties, too — among them corrosion and heat resistance, high tensile strength, excellent workability. And you'll find exactly the combination and degree of these properties you need in one of the thirty grades of Crucible stainless steel. To see what general and technical literature is available to help you make the most of Crucible stainless — or any other Crucible special purpose steel — write for your free copy of the Crucible Publication Catalog. *Crucible Steel Company of America, Henry W. Oliver Building, Pittsburgh 22, Pa.*

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SPREAD LONG.-YIELD to ULTIMATE
SPREAD, TRANS.-YIELD to ULTIMATE
BENDS 105°
HARDNESS
% RED. IN AREA
87,300
86,200
68,200
70,400
22.4
19,200
15,800
4 TD LONG.
3TD T
56.5
±5,000
±5,000
±5,000
±5,000
±2.3
±3,500
±3,000

ANNOUNCING . . . New quality certification cuts fabricating costs

● Mallory-Sharon now certifies physical properties of unalloyed titanium sheet within narrow limits, based on statistical quality control techniques. This policy has resulted in major savings in time, money, and forming equipment for titanium fabricators.

Here's how Mallory-Sharon's certification works: As a purchaser, you will order unalloyed titanium sheet with strength in a specified range (say 60,000 to 80,000 psi). In addition to meeting this specification, we advise you the average strength of material from each heat, and certify that 97.5% of the heat lies within narrow limits (such as plus or minus 5000 psi) of this value.

Since titanium of different strength levels requires different fabrication procedures, dies, etc., this certification means that you can eliminate testing and segregating titanium sheets into different strength levels, and eliminate multiple tooling set-ups.

Here is another first from Mallory-Sharon, leading producer of titanium and titanium alloys. For complete information, write Mallory-Sharon Titanium Corporation, Dept. G-11, Niles, Ohio.

MALLORY Ti SHARON

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lution was to increase torsional properties of the shaft. This could be done by increasing its size or by raising the shaft's hardness. Shafts were being produced of 4100 chromium-molybdenum steel, forged, heat treated complete and machined to finish size. The shafts were already at the upper limits of commercial machining with a Brinell of 363-444. Even if machining problems could be solved, higher through-hardness would result in brittleness which would extend through the axle.

The solution

To bring about the right combination of high fatigue resistance of the surface with good load carrying ability, hardness of the outer periphery had to be increased and backed with a tough core. Induction methods allow the periphery of the shaft to be heated to any desired depth, leaving the core structure undisturbed. The heated portion is then quenched, producing a high hardness (495-555 Brinell in this instance) in the heated case, and leaving the core tough and ductile. The 4100 series steel has good inherent hardenability, responding well to core and surface treatment.

Induction hardened axle shafts have shown a remarkable increase in fatigue life and static torsional properties as compared with the prior through-hardened shafts. In shafts of the same material and size, torsional yield strength has been increased from 100,000-115,000 to 135,000-145,000 psi; ultimate torsional strength has been increased from 130,000-150,000 to 170,000-200,000 psi; twist at yield point from 22-26 deg to 30-35 deg; and surface hardness from 363-444 to 495-555 Brinell.

Field testing

Field tests of induction hardened shafts have verified laboratory test results. Six of the new units were installed in semi-trailers hauling core sand and slag. To date, they have all been free from failures, though they have traveled from 48 to 187% more

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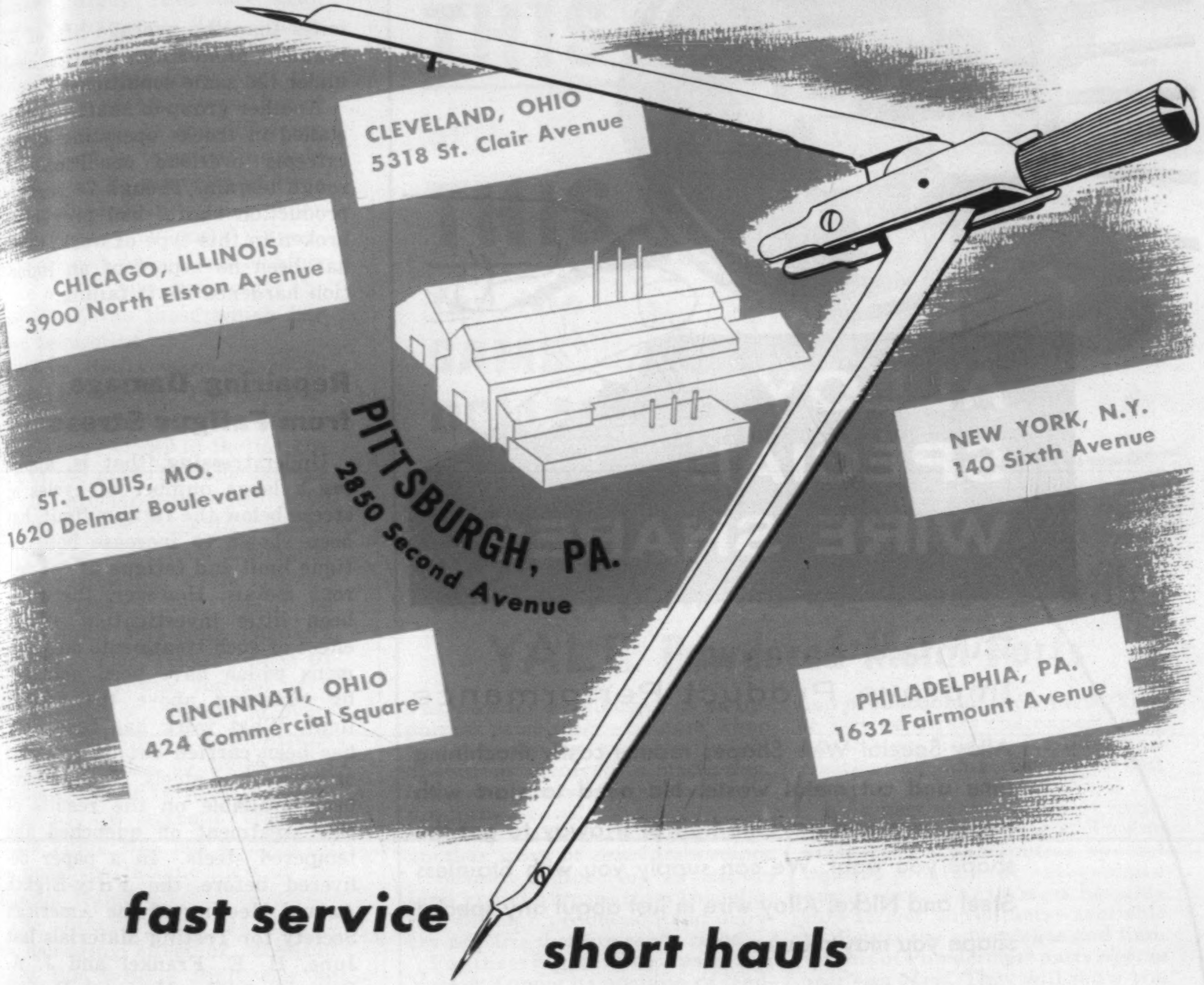
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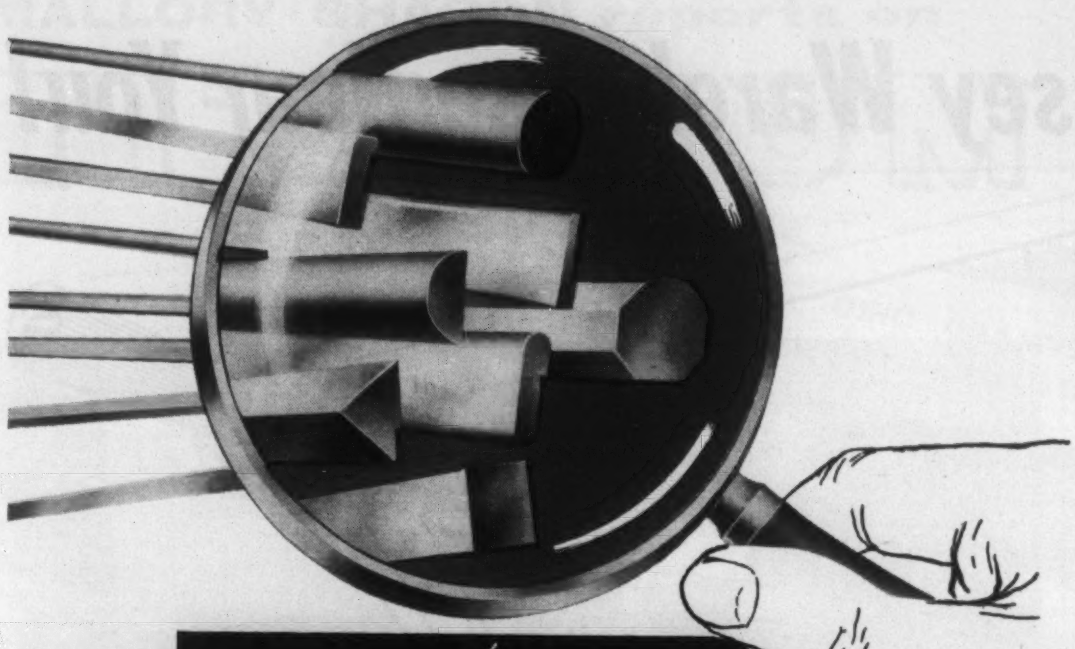

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Contents Noted

miles than the average life of 37 regular production shafts used under the same conditions.

Another group of shafts was installed in trucks operating under extreme overload conditions in rough terrain. Though 75 regular production shafts had previously broken in this type of work, there has been no report of an induction hardened shaft failing.

Repairing Damage from Fatigue Stress

Understressing, that is, applying a large number of cycles of stress below the fatigue limit, has been shown to increase both fatigue limit and fatigue life of ferrous metals. However, there has been little investigation of the effect of such treatments on specimens which have been damaged by stressing above the fatigue limit. What work has been done has been carried out on annealed or normalized steels. No data have been available on the results of this treatment on quenched and tempered steels. In a paper delivered before the Fifty-Eighth Annual Meeting of the American Society for Testing Materials last June, H. E. Frankel and J. A. Bennett of the National Bureau of Standards reported results of the preliminary phase of an investigation to determine effects of such treatments on ferrous metals. Preliminary work has been done on quenched and tempered SAE 4340 steel specimens.

Coaxing, which is the application of a large number of cycles at each of a series of stresses of increasing amplitude, increases fatigue limit of some metals. Most of the work done thus far on the NBS project has been concerned with studying effect of coaxing on both damaged and undamaged specimens. In tests conducted at constant stress amplitude, standard deviation of number of cycles to fracture increased as stress amplitude approached fatigue limit. Specimens coated with a rust-preventive oil during testing showed

For more information, Circle No. 535

➤

Contents Noted

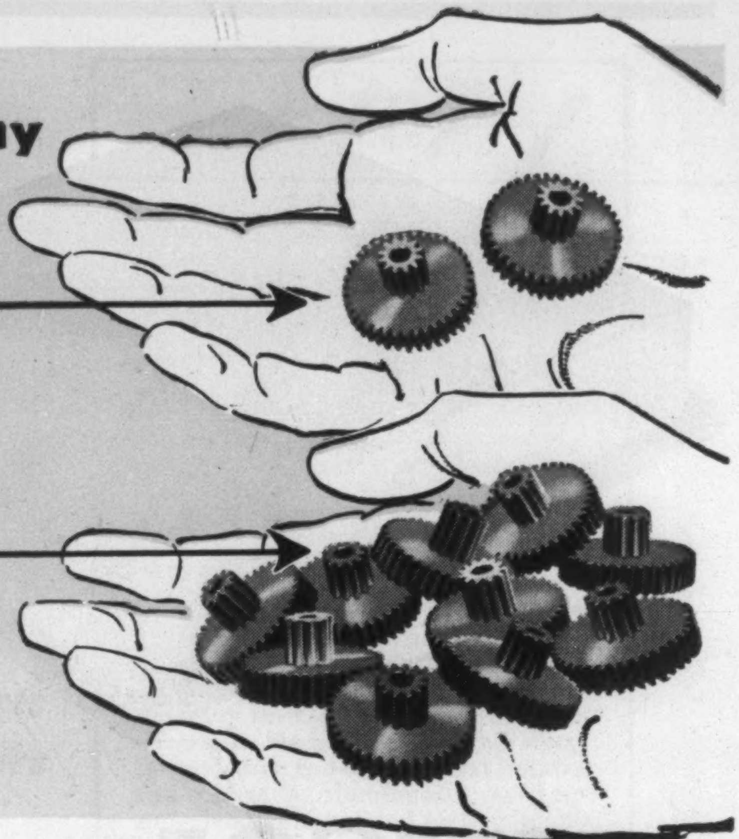
reater fatigue resistance than il-free specimens. The reason or this is still open to question. t did not appear likely that the ffects were due to prevention of orrosion, since 1) the difference as apparent in tests lasting only to 20 min; 2) majority of tests ere conducted in winter when umidity was low and 3) specimens cleaned of oil immediately efore a test gave apparently the ame results as those which had ever been oiled.

Fatigue limits were raised in ll cases by coaxing. The improvement was greater when initial tresses were closer to the fatigue imit of the material. The damage ue to overstressing for 30% ycle ratio at a stress 10% above he fatigue limit was eliminated y understressing, while damage ue to stressing 30% above the atigue limit was only partially liminated. The "repair" effect of nderstressing was verified by a est in which a program of overstressing followed by understressing was repeated 25 times for a umulative cycle ratio at the overstress of 7.6 without fracture. Strain aging was not a factor in he improved fatigue limit of the aterial tested.

The authors point out that if the damaging effect of stressing above the fatigue limit can be eliminated by suitable treatment, it would be of considerable practical importance as well as providing information which would further the understanding of the mechanism of fatigue fracture.

Materials Problems in High Pressure Ducts

The numerous uses to which high pressure air is put in today's aircraft make it imperative to design efficient ducts to carry the air at pressures of at least 275 psig and at temperatures of 300 to 1000 F from its source to its point of use in the airframe. These higher temperatures and pressures have raised knotty problems in designing and selecting



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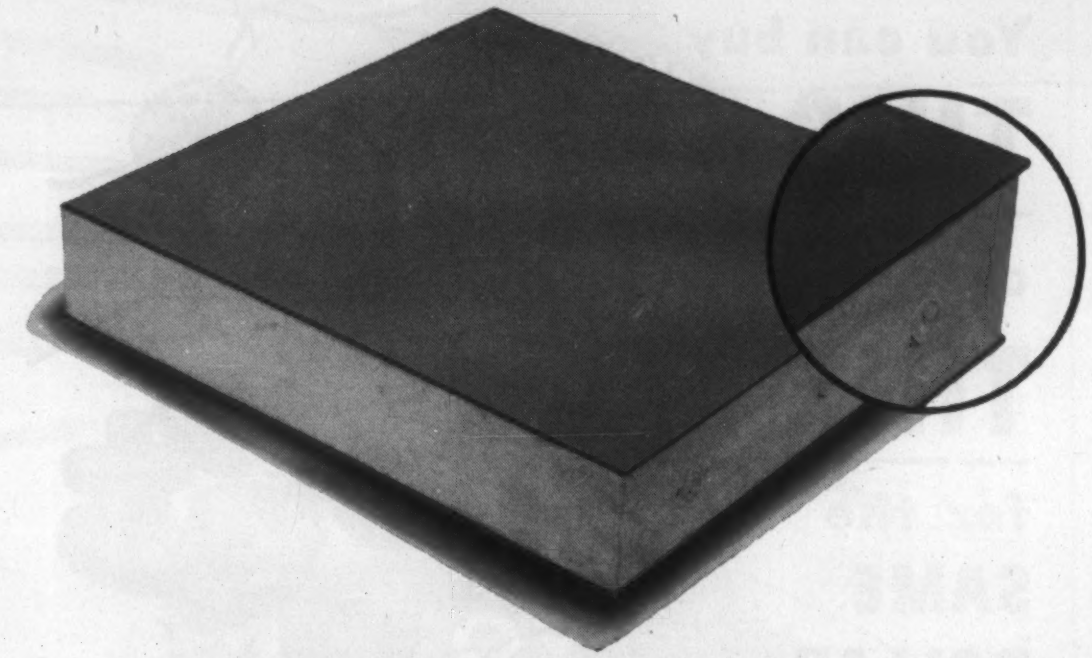

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Contents Note

materials for pneumatic duc Problems are compounded by v brations and variations in te peratures and pressures to whic ducts are subjected. In a pap delivered before the Society Automotive Engineers' Golden A niversary Aeronautic Meeting la October, W. M. Cattrell of Rya Aeronautical Co. detailed sever of the materials problems encou tered in designing ducts for ai craft.

Materials

Most commonly used materia are types 321 and 347 stainle steels, though 19-9DL and 19-9D are becoming increasingly popula because of their greater yield an fatigue strengths. Also under i vestigation are 17-7PH, Incon X, and other alloys which can b age hardened after fabricatio The trend is toward use of highe strength materials in light gages, in order to reduce weigh

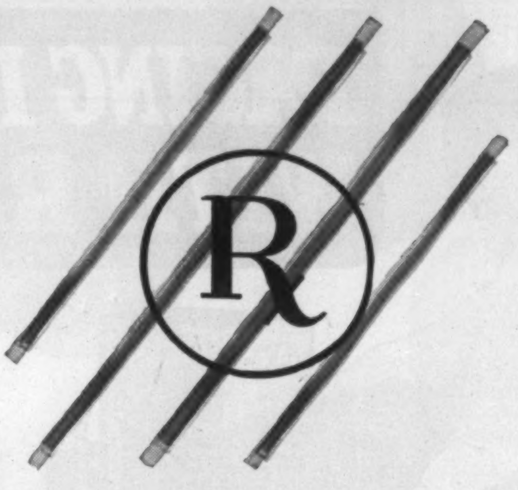
Problem 1 *Weight reduction*—T tanium, both commercially pu and alloyed, is under investigatio as a duct material because of it light weight and high strengt at moderate temperatures. It als has excellent fatigue strengt and corrosion resistance. On th other hand, titanium is more tha 10 times more expensive tha stainless steel and its welding an forming are more costly. Eac specific application must b weighed carefully to determin whether the additional cost i justified.

Problem 2 *Thermal expansion and deflection* — Loops and omega bends, bellows, sliding joints and ball joints are being used to allow for thermal expansion and deflection caused by motion of the aircraft. Each of these methods imposes its own problems in formability of the materials involved.

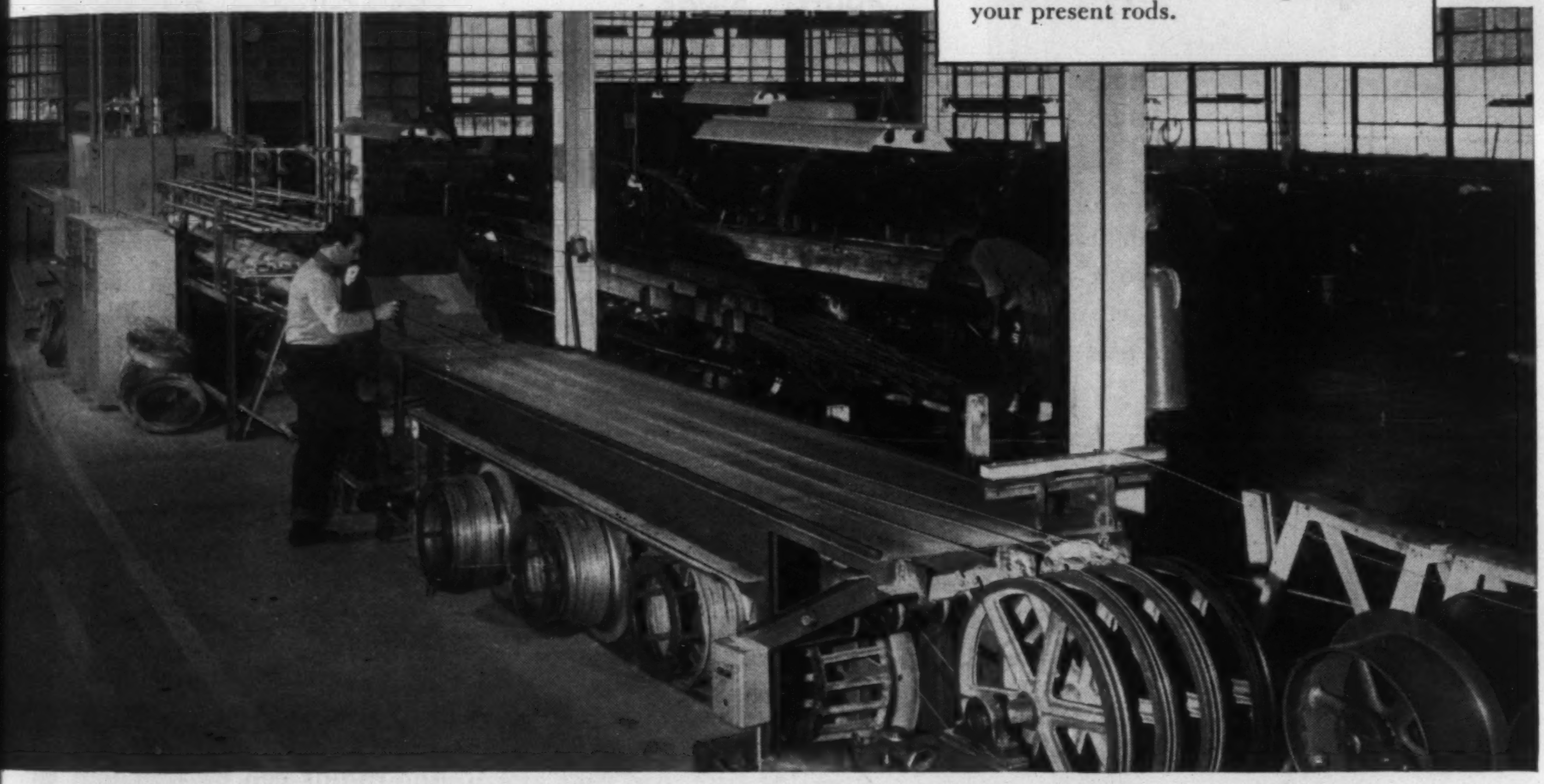
Problem 3 *Insulation* — Surface temperatures of ducts in the vicinity of fuel and hydraulic lines or tanks must be safely below ignition temperature of the combustible materials contained in the lines. There are various methods

Why another plant converted to "HOT RODS" 100%

J. Bishop & Company Platinum Works reports CRYSTOLON* heating elements outlast others by 3-to-1 in Drever furnaces



CRYSTOLON Heating Elements, or "Hot Rods", are a typical Norton ℞ — an expertly engineered refractory prescription for greater efficiency and economy in electric furnace and kiln operation. Made of self-bonded silicon carbide, each rod has a central hot zone and cold ends. Aluminum-sprayed tips and metal-impregnated ends minimize resistance and power loss. Available in standard sizes and interchangeable with your present rods.



One of the Three Drever Electric Furnaces at the Frazer, Pa., tube mill of J. Bishop & Company Platinum Works, specialists in small diameter stainless steel tubing (.008" to 1" O.D.), tubular fabricated parts, surgical instruments and refiners of precious metals.

Wherever it uses silicon carbide heating elements — as in its Drever electric furnaces — J. Bishop & Company has changed over completely to "Hot Rods."

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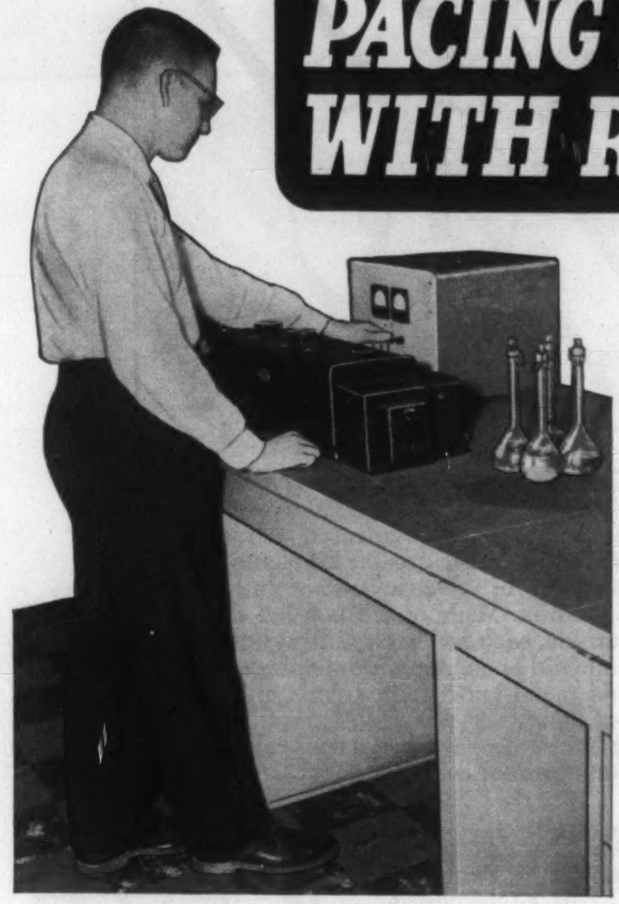

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of insulating these ducts, either with separate insulation assemblies or combining insulation as integral parts of duct segments. Regardless of the type of assembly employed, it should have high thermal insulation properties, be resistant to damage from installation operations, and be easy to handle, and secure.

Glass fiber batting covered with glass cloth impregnated with neoprene has been found to be superior in meeting these specs. Surface coverings for insulation may be either fabric or stainless steel foil, depending on demands of a particular application. Foil has the advantage of permitting use of preformed shapes for complex ducting sections. If the insulation assembly is separate from the duct, it is generally desirable to face inner as well as outer surfaces in order to prevent wicking. Thickness of insulation is determined by allowable heat loss.

Problem 4 *Appropriate formability*—Depending on the desired bend radii, duct bends may be made by forming half-stampings that subsequently are welded together, or by bending tubing to desired configurations. Half stampings are particularly advantageous if bend radii are sharp and quantity of ducts to be produced is small. A duct can usually be bent to a desired configuration if the centerline radius can be kept to a minimum of twice the diameter of the duct.

Designers should be aware that permissible degree of duct bend is a function of the ductility of the material to be formed. Use of multiple-stage forming operations often permits selection of a material that could not be considered if the forming were to be done in a single operation. This is true of materials such as 19-9DL, 19-9DX, Inconel X and titanium. Though unusually hard materials are more difficult to form, their use is justified because their greater strength permits use of lighter gages, thus reducing weight.

(*Book Reviews on p. 210*)

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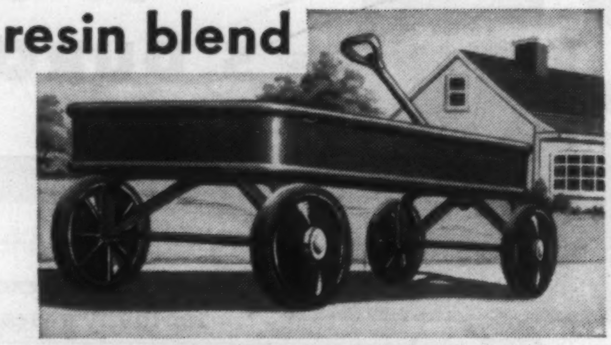
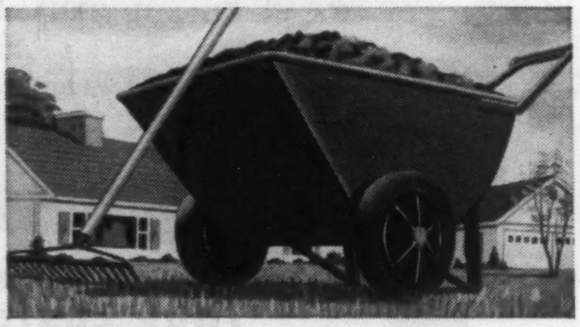
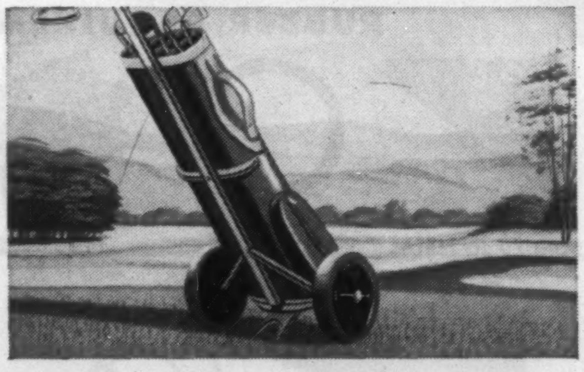
Made of KRALASTIC a rubber-resin blend







Kralastic rubber-resin—proved so outstanding in water meter covers, underground pipe, and in hundreds of other *tough* applications—now gives *wheels* wonderful new *selling* properties!

A leading lawn-mower wheel manufacturer found Kralastic wheels *far* superior to conventional steel or aluminum wheels. And dozens of end product manufacturers are already beginning to incorporate them in *their* products.

Look at the advantages Kralastic wheels offer and you'll see why!

- **lighter than aluminum!**
- **smooth, quiet running—never need oil!**
- **can't rust, rot, or corrode!**
- **will bounce ten feet high from concrete—unharmed!**
- **abrasion resistant!**
- **non-warping, resistant to weather and most chemicals!**
- **thoroughly, permanently colored!**
- **quickly injection molded—relatively inexpensive!**

Look for Kralastic in the products *you* buy and sell—in wheels, drawer slides, pulleys—wherever toughness and lack of friction are important. *Feature the advantages Kralastic offers.* It will help you sell the *complete product.*

And if you're a manufacturer, see what Kralastic® can mean to *you.* Write us today.

Naugatuck Chemical

Division of United States Rubber Company
Naugatuck, Connecticut

BRANCHES: Akron • Boston • Charlotte • Chicago • Los Angeles • Memphis • New York • Philadelphia • IN CANADA: Naugatuck Chemicals, Elmira, Ontario
Rubber Chemicals • Synthetic Rubber • Plastics • Agricultural Chemicals • Reclaimed Rubber • Latices • Cable Address: Rubexport, N.Y.

For more information, turn to Reader Service Card, Circle No. 497

NOW—ROTH RESEARCH DEVELOPS A

NEW, NON-POROUS RUBBER WITH A SOFTNESS OF ONLY 5 DUROMETER!

- Makes an excellent seal for many gases and liquids.
- Cushioning range from Shore "A" Durometer readings of 5 and up.
- Can be molded to suit your requirements, or to meet those formulated for you by ROTH technicians.
- Sample and specifications available to engineers and rubber buyers. Write today.

BASIC SPECIFICATIONS

(Sample: Hardness 10 to 15 Durometer)

Tensile Strength (PSI)........................560
Elongation..800%
Compression Set 22 hrs. @ 158°F............41%

ROTH CAN MEET YOUR CUSTOM MOLDED RUBBER REQUIREMENTS

RUBBER BONDED TO METAL — GASKETS — IMPELLERS — TRANSFORMER CASES
VIEWING HOODS — SHOCK MOUNTS — SANDING MACHINE PADS.

WRITE—WIRE—PHONE

RR ROTH RUBBER COMPANY

1860 S. 54th Avenue, Chicago 50, Illinois

For more information, turn to Reader Service Card, Circle No. 482

Contents Noted

Books . . .

Plastics for Corrosion-Resistant Applications. *Raymond B. Seymour and Robert H. Steiner. Reinhold Publishing Corp., New York 22, N. Y. 1955. Cloth 6 by 9 in. 423 pp. Price $7.50.*

Dealing primarily with the application of plastics in corrosive environments, the treatment is designed to supply information on plastics as materials of construction. Commercially available materials are reviewed thoroughly, and an attempt is made to show the effect of structure on chemical resistance. In general, the less common materials are mentioned only briefly. Several chapters are included on the applications of thermoplastics, and a section is devoted to design. Each chapter contains a list of references to sources of additional information.

Chemists and engineers will find this book valuable as a source of comparative data on the chemical resistance of coatings, linings, pipe and thermoplastic structures.

Powder Metallurgy. *Organization for European Economic Co-operation, Washington 6, D. C. 1955. Paper 6 by 9½ in. 309 pp. Price $3.00.*

This is a report prepared by the 28 members of the Powder Metallurgy Mission who visited the United States to study powder metallurgy developments. The Mission visited 43 manufacturing plants, universities and other research laboratories. The report covers electrical and magnetic applications, hard metals, tungsten wire production, cermets, engineering powders and structural parts, pressing processes and equipment, furnaces, standards and quality control. Engineers and metallurgists engaged in the production and application of metal powders will find much of interest in this volume.

Proceedings, Eleventh Annual Meeting Metal Powder Association. *Metal Powder Assn., New York 17, N. Y. 1955. Paper 6 by 9 in. Vol 1, 113 pp. Vol 2, 74 pp.*

Volume 1, General Session on

It's tough—for a copywriter—to see this white space going to waste. But it sure tells a story! Let this entire page represent the area of plain tube required for your heat transfer. The same heat transfer surface can be concentrated in relatively the space occupied by this block of type by using Wolverine Trufin*—the integral finned tube. Trufin boosts capacity—saves space—cuts costs. Send for Trufin Catalog.

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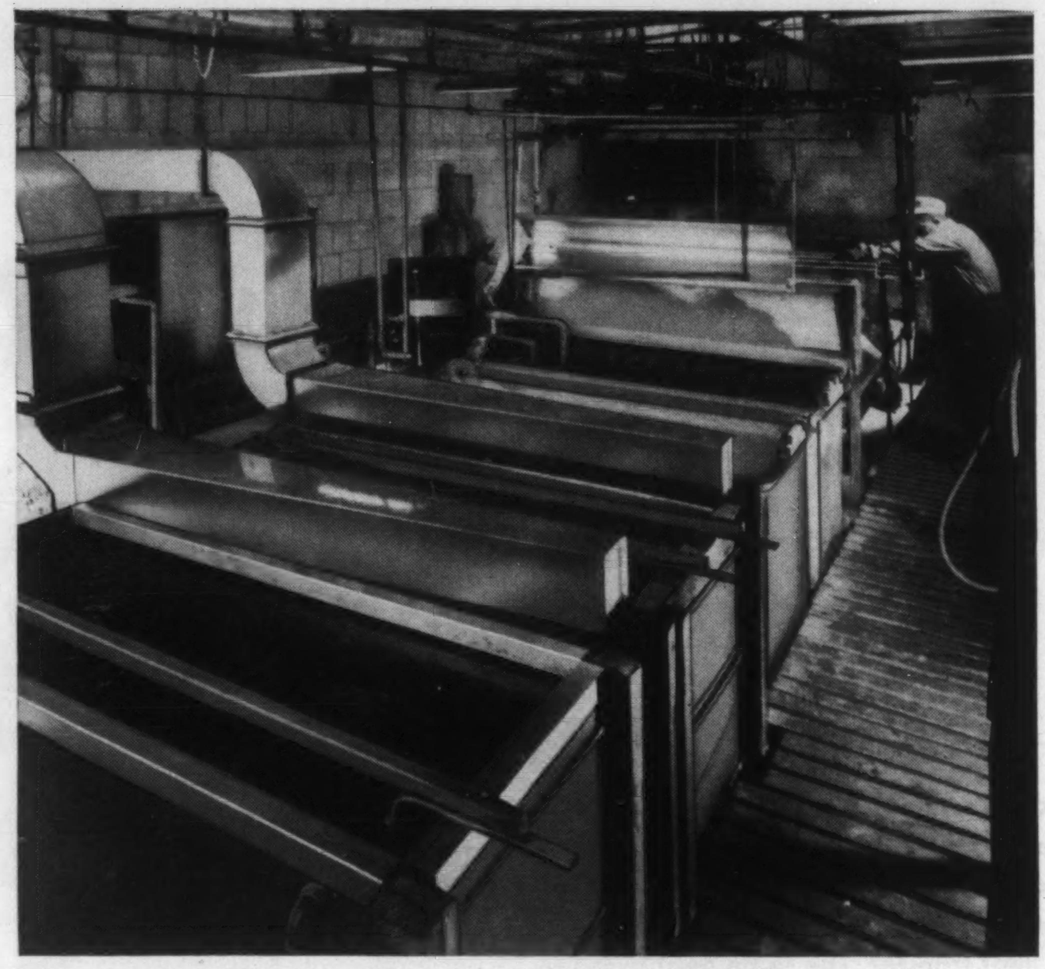
Wolverine Trufin is available in Canada through the Unifin Tube Company, London, Ontario

For more information, Circle No. 519



Choosing Chemicals for Aluminum Treatment Prior to Anodizing

Better production processes and techniques are today's answer to the growing industrial and consumer demand for aluminum products.

In one area, that of anodizing pre-treatment, several general production changes are occuring. For example, many manufacturers seeking a satin finish prior to anodizing have stopped using an alkaline etchant for both cleaning and etching. By forcing it to do double duty, etching solution life was shortened and rejects were high. Selective etching and variations in reflectivity often occurred.

The answer was to divide cleaning and etching into two steps. By using Diversey No. 202 they are assured of both successful removal of oils, greases and marking inks *and* effective keying of the surface for a uniform etch. This cleaning action prolongs the life of the etching solution by freeing it of large amounts of contamination. Then Aluminux, an easily controlled etchant, is used to produce a uniform, diffused satin etch. In addition to being an outstanding etchant, Aluminux cuts costs two ways: 1) It eliminates scale problems by holding greater amounts of sodium aluminate in solution and 2) This greater contamination capacity makes etching solutions effective for longer periods.

To prevent smut build-up and drag-in of alkaline solution to the anodizing bath, Diversey No. 514 is used following etch. No. 514 thus prolongs anodizing solution life. It also assures an even anodic coat by providing a uniform, de-oxidized surface prior to anodizing. A granular acidic product, No. 514 emits no toxic gases, is easier to handle than acids in carboys, is used at room temperatures and is simple to control.

For additional information on No. 202, Aluminux and No. 514 for satin finished aluminum prior to anodic coating, write to The Diversey Corporation, 1820 Roscoe Street, Chicago 13, Illinois.

For more information, turn to Reader Service Card, Circle No. 463

Contents Noted

Books . . .

Powder Metallurgy, contains 9 papers dealing with such subjects as finishing and plating of metal powder parts, pre-alloyed steel powders, small volume production of parts, and titanium powder metallurgy.

Volume 2, Electronic Core Session, contains 9 papers covering such topics as specifying iron powder cores, applications of ferrites, and quality of magnetic powder cores.

Instruments for Measurement and Control. *Werner G. Holzbock. Reinhold Publishing Corp., New York 22, N. Y. 1955. Cloth 6 by 9 in. 371 pp. Price $10.00.*

This book is designed to acquaint the reader with the types of instruments available for the measurement and control of process variables and to serve as a reference to available instruments for specific applications. Covered are instruments for measuring temperature, humidity and moisture, pressure, flow, liquid level, density, viscosity, speed and others for the determination of physical properties and for chemical analysis. Included is a chapter on trends which discusses the development of centralized systems, miniaturization and digital computers.

Industrial Furnaces, Volume II. *W. Trinks. John Wiley & Sons, Inc., New York, N. Y. 1955. Cloth 6 by 9 in. 358 pp. Price $10.00.*

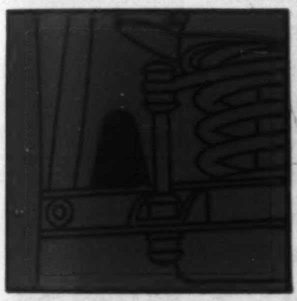
The third edition of this well-known book follows the arrangement used previously. Chapters deal with fuels and electric energy, combustion devices and heating elements, control of furnace temperature and atmosphere, labor saving appliances, and safety measures. A chapter is devoted also to a critical comparison of fuels and furnace types. Each chapter has been revised extensively to cover recent developments.

Handbook of Engineering Materials. *Douglas F. Miner and John B. Seastone, editors. John Wiley*

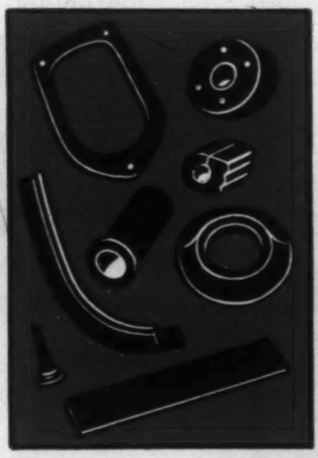
In over 100 places,

Enjay Butyl rubber parts

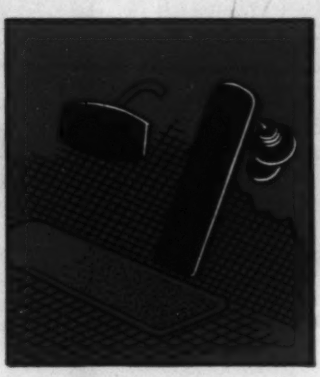
add to Pontiac performance



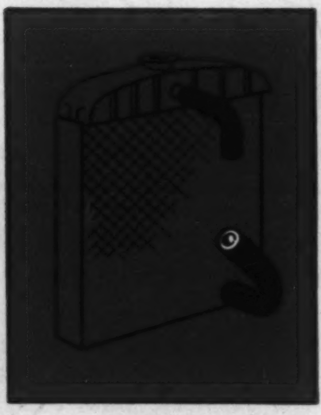
Axle bumper



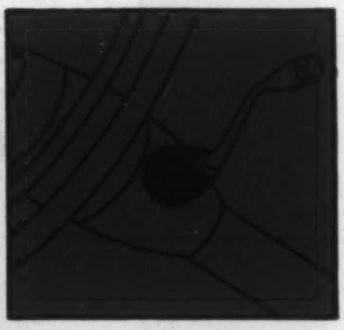
Body seals, gaskets, insulators, pads, grommets, etc.



Brake and accelerator pedal pads, bellows



Radiator and heater hoses, ducts



Gearshift lever cover

Pontiac has been using parts made of Enjay Butyl since 1946. The great '56 model now incorporates more than 100 parts made from this super-durable rubber, adding to its performance, style and value. These parts have amazing resistance to deterioration and will easily last the life of the car.

Among the many advantages of Enjay Butyl are *price* and *ready availability*. And it is now available in non-staining grades for white and light-colored parts. Extensive laboratory and testing facilities are at your service. For the full story, contact the Enjay Company today.

ENJAY
BUTYL

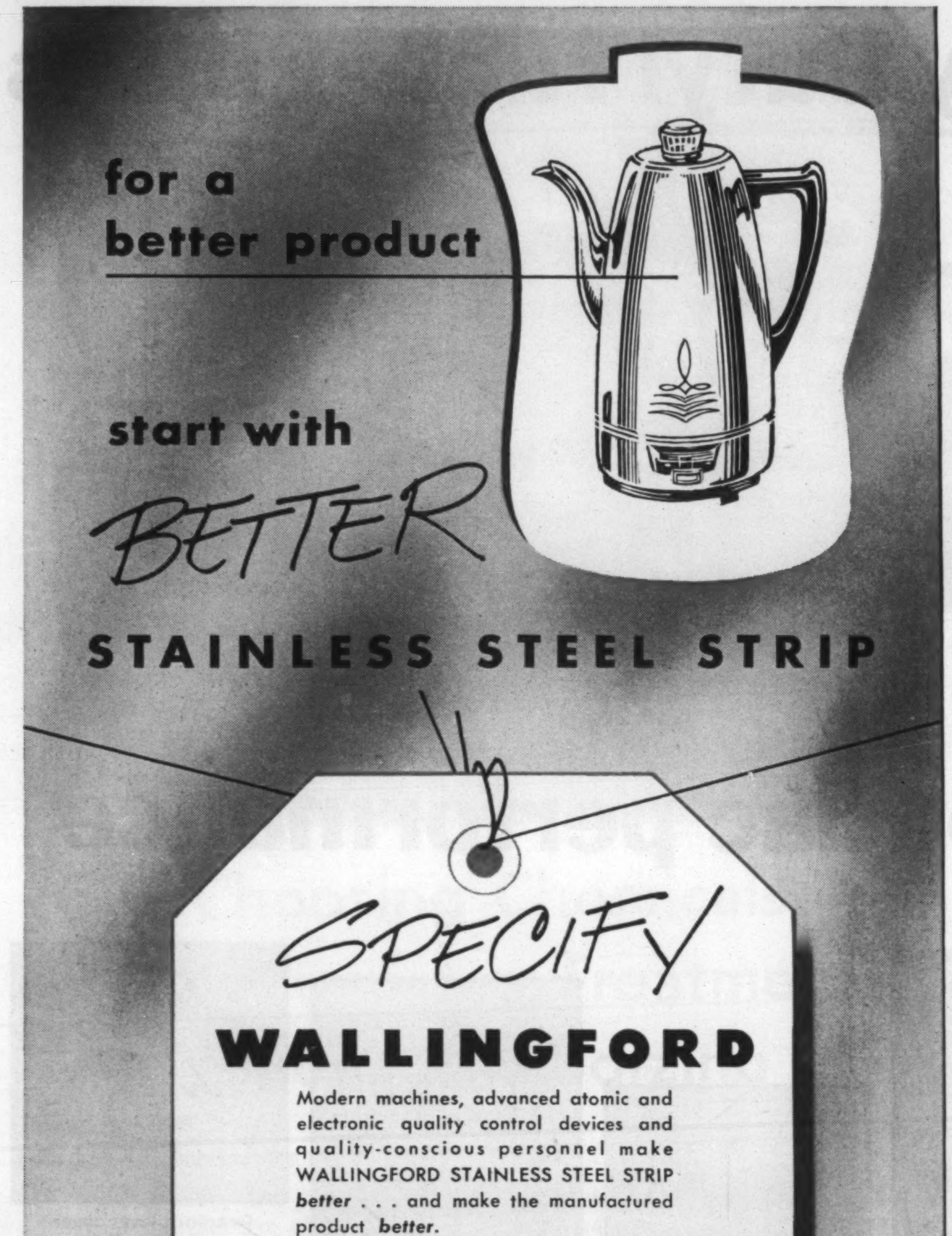
Enjay Butyl is the super-durable rubber with *outstanding* resistance to aging • abrasion • tear • chipping • cracking • ozone and corona • chemicals • gases • heat • cold • sunlight • moisture

ENJAY

ENJAY COMPANY, INC., 15 West 51st Street, New York 19, N. Y.
District Office: 11 South Portage Path, Akron 3, Ohio

35 SUCCESSFUL YEARS OF LEADERSHIP IN SERVING INDUSTRY

For more information, turn to Reader Service Card, Circle No. 525



for a
better product

start with
BETTER
STAINLESS STEEL STRIP

SPECIFY
WALLINGFORD

Modern machines, advanced atomic and electronic quality control devices and quality-conscious personnel make WALLINGFORD STAINLESS STEEL STRIP *better* . . . and make the manufactured product *better.*

Better strip means better output, too. WALLINGFORD STAINLESS STEEL STRIP gages uniformly, draws easily, punches cleanly . . . to reduce spoilage and tool costs.

- THINNESSES TO .002" • ACCURACY TO ± .0001" • SPECIAL SECTIONS ROLLED TO YOUR EXACT DESIGN

A visit to our offices and plant will convince you that Wallingford quality is unmatched.

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WALLINGFORD
STEEL CO.
WALLINGFORD, CONN., U.S.A.

STAINLESS • ALLOY • HIGH CARBON • LOW CARBON
STRIP • STAINLESS WELDED TUBES AND PIPE

For more information, turn to Reader Service Card, Circle No. 460

Contents Noted

Books . . .

& Sons, Inc., New York, N. Y. 1955. Cloth 6 by 8½ in. 1382 pp. Price $17.50.

This handbook was designed to give the engineer a single source of data on the usual materials of manufacturing and construction. The aim is to present sufficient data to form a useful guide to the selection of a wide range of materials and to suggest sources of more detailed information.

The book is divided into 4 main sections: general information on specifications and standards, statistics and mathematical and physical tables; metals, including ferrous alloys, aluminum, magnesium, copper, zinc, nickel and many special purpose alloys; nonmetallic materials, including wood, paper, fibers, plastics, rubbers, organic finishing materials and ceramic materials; construction materials, including cement and concrete, roadbed materials, timber, rope and glass products.

Designers of product or construction projects, materials engineers and others concerned with the applications of materials will find this book a very valuable addition to their reference shelves.

Modern Manufacturing Processes. *Joe L. Morris. Prentice Hall, Inc., Englewood Cliffs, N. J. 1955. Cloth 6 by 9 in. 533 pp. Price $9.35.*

This book is designed as a text to be used in a study of present manufacturing processes. Included are chapters on the development of iron and steel products, foundry practices, working of metals, heat treatment of metals, welding processes, machining, forming, gaging and inspection. Each chapter contains a list of questions and references to additional information.

Reports . . .

Metal - ceramic bonds APPLICATION OF FUNDAMENTAL CONCEPTS OF BONDING METALS AND CERAMICS. *Harold A. Barr, Louis Marchi, Harold H. Rice, James A. Stavro-*

Find out today how

STYRON 475 SHEET

can make money for you!

Plastics Sales Department, Dept. PL 490HH-1,
The Dow Chemical Company, Midland, Michigan.
Please rush technical data on Styron 475 sheet and nearest source of supply:

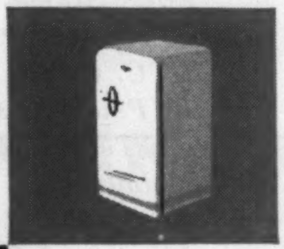
Name and title____
Firm name____
Types of product manufactured____________________________
Address____
City____________________ Zone______ State______________

DOW

HIGH FABRICATION COSTS A PROBLEM?

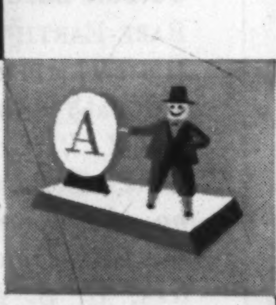
Dow has the answer in STYRON 475 PLASTIC SHEET

Many complicated refrigerator and appliance parts like freezer doors and crisper boxes are made with easily formed Styron® 475 sheet!

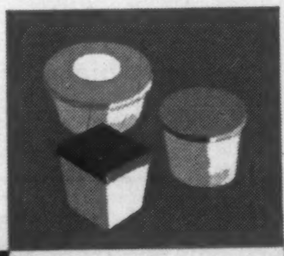


There's no limit to colorful, high-impact Styron sheet's applications in the novelty fields!

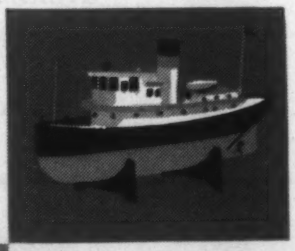
Many beautiful three-dimensional displays and signs are formed of low-cost Styron 475 sheet!

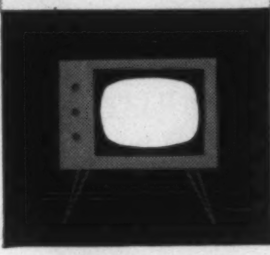


The list of its advantages below shows why more and more packaging men have turned to dependable Styron 475 sheet!



Versatile Styron 475 sheet sets the pace for realistic detail, extra play value and longer play life in today's fastest-selling toys!





Styron 475 sheet is the choice of many radio and TV manufacturers for masks, back and tube enclosures and insulating shields!

YOUR PRODUCT GOES HERE

You can use these Styron 475 sheet advantages to cut your operating costs—

1. Economical
2. Will not corrode, rust or tarnish
3. Easily formed and fabricated (punched, die-cut, stamped, vacuum-formed)
4. Adaptable to most painting and printing methods
5. Excellent resistance to water and moistures
6. Will not support mildew, mold and fungi
7. Lightweight
8. Chemically compatible with a majority of packaging materials
9. Reusable or disposable
10. Wide range of opaque and semitranslucent colors
11. Nontoxic
12. Has good chemical resistance

Yes, imaginative engineering minds have made plastics a basic part of almost every industry you can name. Styron 475 sheet is a high impact polystyrene plastic formulation produced as a sheet in a variety of sizes, thicknesses and colors. Developed by Dow through advanced extrusion techniques, it is a vital factor in the swing to plastics as a profitable production material. Styron 475 sheet is available from leading manufacturers throughout the country. There are also leading fabricators nearby ready to form to your specifications. Return the coupon above today, and put Dow's experience and leadership in plastic sheet to work for *you*. Our pledge: *Prompt*, personal attention to your needs.

you can depend on DOW PLASTICS

DOW

For more information, turn to Reader Service Card, Circle No. 348

ROLLE adds precision investment casting facilities

Rolle Manufacturing Co., long a recognized supplier of fine magnesium and aluminum sand and permanent mold castings, takes pleasure in announcing an important new facility to industry and the military. With the addition of Scott Casting & Manufacturing Corp., Rolle can now offer precision investment casting of ferrous and non-ferrous metals as part of its complete foundry service.

Of the many casting techniques available, only *one* is right for any given casting. By calling in Rolle casting specialists to recommend that technique you avoid any chance of error or bias. These men are familiar with both sand *and* precision casting techniques. And they are free to advise whichever method is indicated by quantity, tolerances, costs, etc.

Should investment casting be the answer, you can be sure of the same attention to detail, rigorous quality control, and top casting performance from Scott castings that have always characterized Rolle's sand and permanent mold castings.

WRITE NOW *for complete information on Rolle facilities for cutting casting costs . . . solving casting problems.*

for complete foundry service

ROLLE
Manufacturing Company
Cannon Avenue, Lansdale, Pa.

For more information, turn to Reader Service Card, Circle No. 450

Contents Noted

Reports . . .

lakis. Armour Research Foundation, Chicago, Ill. Oct. 1953. 49 pp. photos, drawings, tables. Available from Library of Congress, Photoduplication Service, Publications Board Project, Washington 25, D.C. Mi $2.75, ph $6.50. PB117936

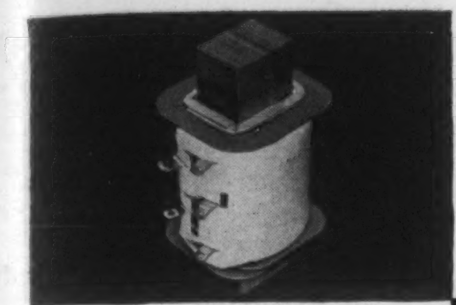
Metals I. DEFORMATION STUDIES OF METALS AT ELEVATED TEMPERATURES. II. IRON-CHROMIUM-NICKEL TERNARY SYSTEM. III. EFFECT OF STRUCTURE AND COMPOSITION ON THE STRENGTH PROPERTIES OF STAINLESS STEEL. *N. J. Grant, H. C. Chang, F. C. Monkman, P. E. Price. Massachusetts Institute of Technology, Department of Metallurgy, Cambridge, Mass. Aug. 1954. 3 pp. Available from Library of Congress, Photoduplication Service, Publications Board Project, Washington 25, D. C. Mi $1.50, ph $1.50.* PB117907

Colbalt-base alloy EFFECT OF RARE-EARTH ADDITIONS ON THE HIGH-TEMPERATURE PROPERTIES OF A COBALT-BASE ALLOY. *J. E. Breen and J. R. Lane. U. S. Naval Research Laboratory. Apr. 1955. 10 pp. photos, graphs, tables. Avaliable from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. 50 cents.* PB111687

Three alloys of same base composition but with 0 to 2% rare earths added were cast from a split heat. Stress rupture tests were run at 1500, 1600, and 1700 F. High-temperature strength and ductility increased in both as-cast and aged material at all temperatures, with greatest benefit occurring at 1500 F. No improvements in room-temperature tensile properties were noted.

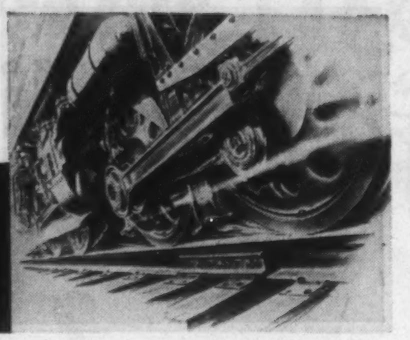
Extruded titanium EXTRUSION OF TITANIUM. *Alvin M. Sabroff, W. Maxwell Parris, and Paul D Frost. Battelle Memorial Institute Columbus, Ohio. Mar. 1955. 77 pp photos, drawing, graphs, tables Available from Office of Technica Services, U. S. Department o Commerce, Washington 25, D. $2.00* PB11169

Extrusion tests were conducte on unalloyed titanium and T

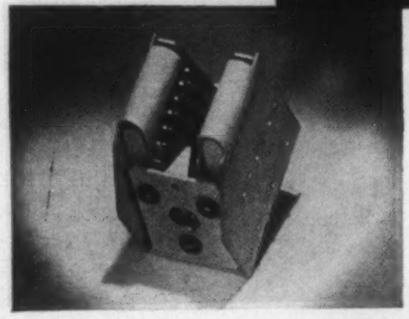


DIELECTRIC STRENGTH. National Vulcanized Fibre gives electrical parts high dielectric strength—plus toughness and excellent forming properties. Has ideal application as insulation.

NATIONAL
VULCANIZED
FIBRE



DURABLE—TOUGH—RUGGED. National Vulcanized Fibre rail joint insulation withstands years of continuous exposure and heavy pounding of today's high-speed railroading. Will not corrode or deteriorate.

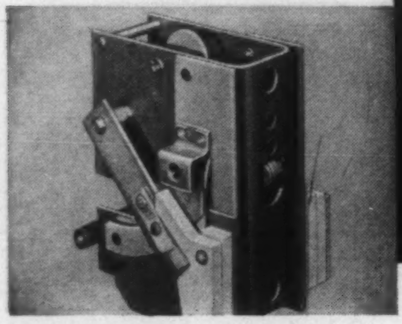


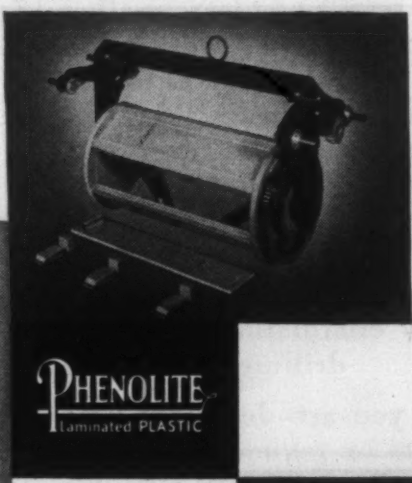
ARC RESISTANCE. In circuit breakers, National Vulcanized Fibre safely curbs electrical arcing without carbonizing or tracking. Easy to bend, punch and form. Light in weight. Heat-and-shock resistant.

FOR MEN WITH IMAGINATION . . .

two materials of unlimited application

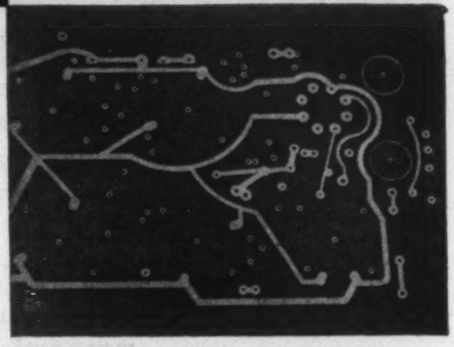
MACHINABILITY—MECHANICAL STRENGTH. New paper-base Phenolite not only has excellent arc resistance, but superior machining qualities as well. Great compressive and tensile strength.





PHENOLITE
Laminated PLASTIC

CHEMICAL RESISTANCE. Chemical-resisting grades of Phenolite are unaffected by most corrosive fluids and atmospheres. Retain high strength, resiliency and dimensional stability.



COMPACT DESIGN—ECONOMY—HIGH TEMPERATURE RESISTANCE. Printed circuits made of copper-clad Phenolite permit compact design, simplify production, reduce assembly time.

Here are six ideas to spur your imagination. They only *suggest* the many things that can be done with National Vulcanized Fibre or Phenolite Laminated Plastic.

The full list of current uses for these materials would more than fill this page and many more pages! Yet more are coming up almost every day. For NVF is not only the world's largest producer of vulcanized fibre. We also make a fulltime job of thinking up new improvements to our products—and new ways of using them to improve *yours*. Result: designers call our materials the most versatile ever.

Looking for an easy, economical way to improve production—or products? Team up with NVF. We're prepared to assist you all the way from initial design to the delivery of precision fabricated parts. Our new 16-page Catalog will give you full information about our products and services. Write for it on your business letterhead to Dept. D-11.

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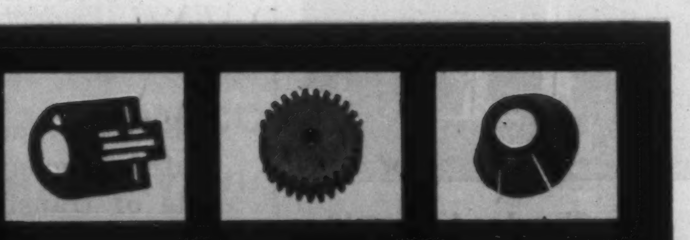
VULCANIZED FIBRE CO.
WILMINGTON 99, DELAWARE

In Canada: **National Fibre Company of Canada, Ltd.** • Toronto 3, Ont.

Also Manufacturers of Peerless Insulation,
Materials Handling Receptacles,
Vul-Cot Wastebaskets and Textile Bobbins.

Typical parts fabricated by NVF



For more information, turn to Reader Service Card, Circle No. 503

How About

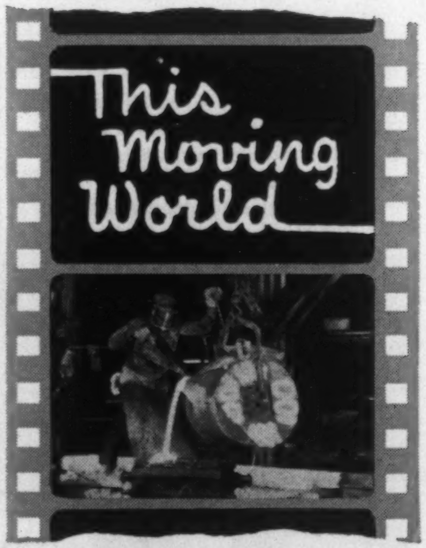
Pearlitic Malleable ?

Toughness . . . Ductility . . . Impact Resistance in Easily Machined Castings

Malleable iron is a cast ferrous alloy heat treated to a remarkable combination of toughness, strength, ductility and machinability. It can be cast close to final form and, unlike most cast material, can be further formed by press or coining operations greatly reducing machining cost. Holes often can be punched eliminating expensive drilling operations.

Whether you are designing new products or reviewing current production it will pay you to consider malleable. Call a malleable foundry and have their engineers go over your parts with you. They can give you information and suggestions to help you design better products that can be made at lower cost.

Send for "Malleable Iron Facts" useful information on Malleable properties and uses.



Schedule a showing of the Malleable Founders' Society Technicolor sound film, "This Moving World". The story of Malleable Iron — how it is made, tested and used. Available on request to groups of production men, engineers, students or others.

Ask your malleable castings supplier or write to the Malleable Founders' Society, Union Commerce Building, Cleveland 14, Ohio

Malleable
FOUNDERS' SOCIETY

1800 Union Commerce Building   Cleveland 14, Ohio

For more information, turn to Reader Service Card, Circle No. 452

Reports . . .

3Mn-complex alloy to study effec
of extrusion temperature and di
design and to evaluate variou
lubricants and die materials. Lu
bricants containing graphite
molybdenum disulfide, and mic
produced acceptable surface fin
ishes. Best results were obtaine
with these materials suspended i
a Bentone grease. Titanium car
bide, chromium carbide, and co
balt-base alloys showed promis
as die materials.

Wear of materials FRICTION
WEAR, AND SURFACE DAMAGE OF
METALS AS AFFECTED BY SOLI
SURFACE FILMS. *Edmond E. Bis-
son, Robert L. Johnson, Max A
Swikert and Douglas Godfrey. U
S. National Advisory Committe
for Aeronautics. May 1955. 60 pp
photos, drawing, diagrs, graphs
tables. Order from National Ad-
visory Committee for Aeronautics
1512 "H" St., N. W., Washington
25, D. C.* PB117580

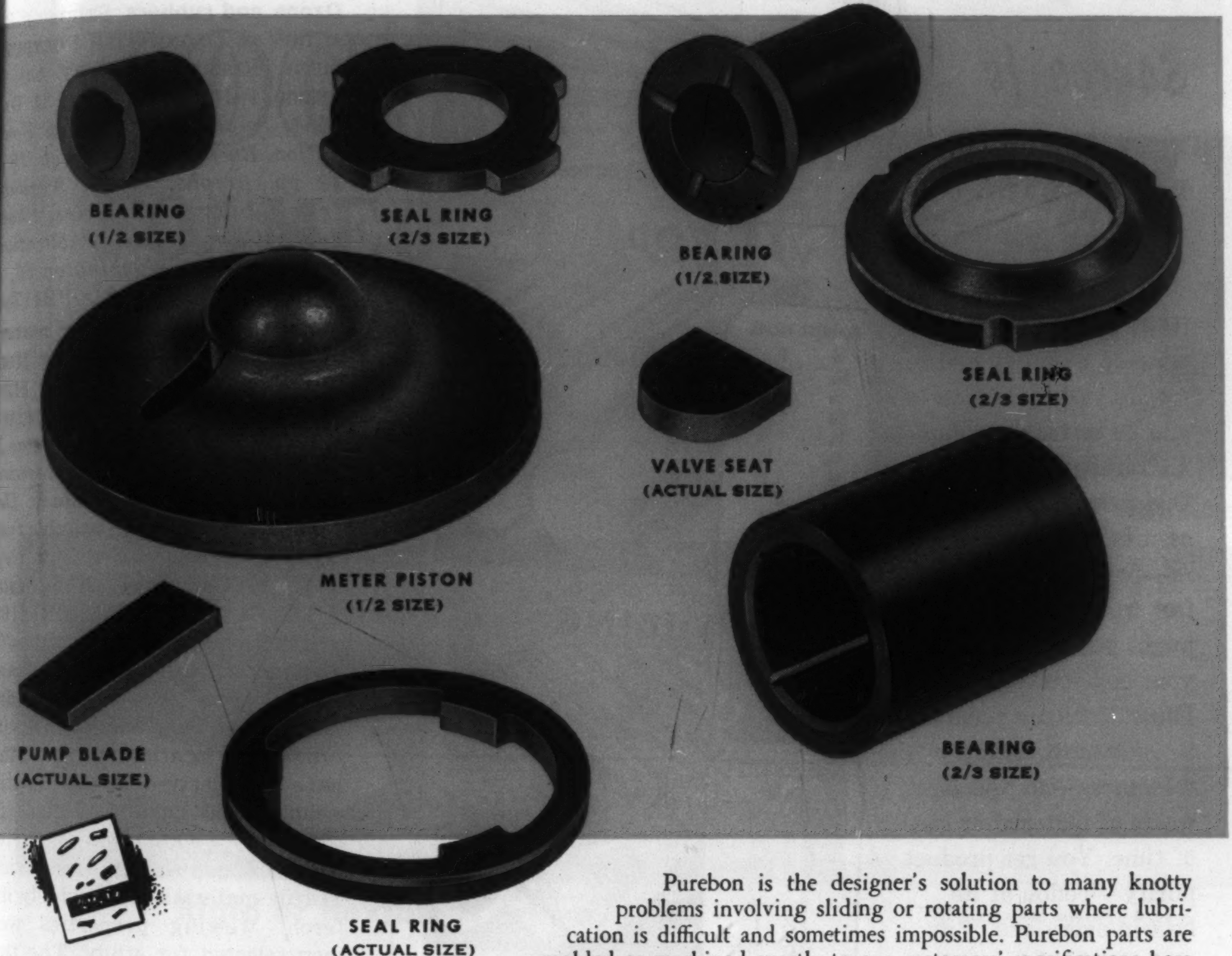
Summary of NACA results of
friction and wear investigations
from 1946 to 1954. Results are
consistent with theoretical predic-
tions that solid surface films of
low shear strength can serve to
reduce both friction and surface
damage. Metallic oxides show tha
ability of materials to form sur-
face films is an important facto
in wear.

Low temperature and material
STUDIES IN THE BEHAVIOR OF CE
TAIN NON-FERROUS METALS A
LOW TEMPERATURES. Final repo
vol. II under contract DA-36-03
sc-15393. *Alfred Bomemann an
Theodore Gela. Stevens Institute
Technology. Peirce Memorial La
oratory for Metallurgy, Hoboke
N. J. Dec. 1953. 79 pp. photo
diagrs, graphs, tables. Availab
from Library of Congress, Phot
duplication Service, Publicatio
Board Project, Washington
D. C. Mi $3.75, ph $10.25.*
PB1177

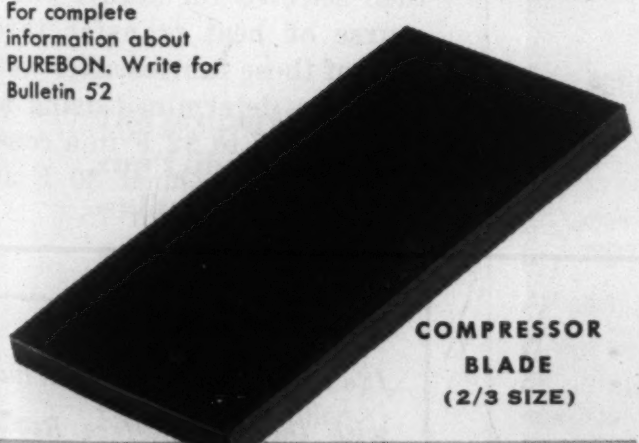
Effect of additions of lead, b
muth, antimony and zinc upon t
rate of transformation of wh
to the brittle gray variety of

. . . the *solution* to your Lubrication problem is here . . . PUREBON

Carbon-graphite especially designed for mechanical applications.


BEARING
(1/2 SIZE)
SEAL RING
(2/3 SIZE)
BEARING
(1/2 SIZE)
SEAL RING
(2/3 SIZE)
VALVE SEAT
(ACTUAL SIZE)
METER PISTON
(1/2 SIZE)
PUMP BLADE
(ACTUAL SIZE)
BEARING
(2/3 SIZE)
SEAL RING
(ACTUAL SIZE)

For complete information about PUREBON. Write for Bulletin 52


COMPRESSOR
BLADE
(2/3 SIZE)

Purebon is the designer's solution to many knotty problems involving sliding or rotating parts where lubrication is difficult and sometimes impossible. Purebon parts are molded or machined exactly to our customers' specifications here in our own plant, under our close supervision and inspection. *Because of the diversified characteristics of Purebon, applications are limited only by the designer's imagination.* If you have a problem involving insufficient lubrication at critical points of friction, our design engineering department will be happy to work with you toward its swift and successful solution.

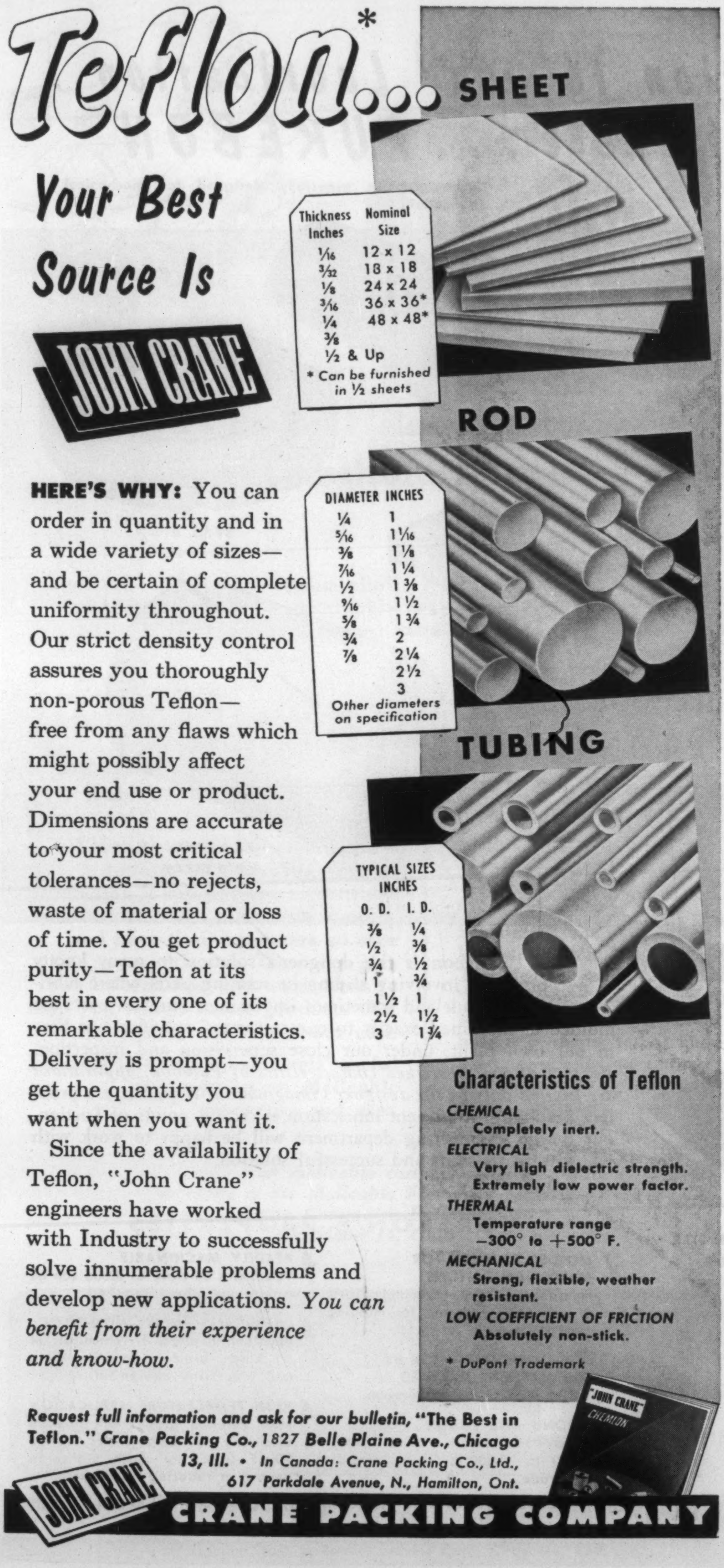
PUREBON'S PROPERTIES

1. ***MOLDED TO SIZE—FOR MANY APPLICATIONS***
   Tolerances of approximately 1½% of dimension required for molding most shapes.
2. ***SELF-LUBRICATING—OR BY THE MATERIAL HANDLED***
   Varies with grade of Purebon.
3. ***STRONG AND TOUGH***
   Transverse strength varies from 4,000 to 13,000 lb./sq. in. according to grade.
4. ***READILY MACHINABLE***
   Tolerances as close as .0005 can be maintained where required.
5. ***CHEMICALLY INERT—NON-TOXIC***
   Resistant to attack by chemicals of all kinds, used in food handling and processing equipment.
6. ***HIGH TEMPERATURE APPLICATION***
   Most Purebon grades will operate efficiently in temperatures up to 700°F in air or much higher in neutral or reducing atmosphere.

Leaders for over 40 YEARS in PURE CARBON PRODUCTS

PURE CARBON CO., INC.
450 HALL AVENUE
ST. MARYS, PENNSYLVANIA

For more information, turn to Reader Service Card, Circle No. 340



Teflon*... SHEET

Your Best Source Is

JOHN CRANE

Thickness Inches	Nominal Size
1/16	12 x 12
3/32	18 x 18
1/8	24 x 24
3/16	36 x 36*
1/4	48 x 48*
3/8	
1/2 & Up	

* Can be furnished in 1/2 sheets

ROD

DIAMETER INCHES

1/4	1
5/16	1 1/16
3/8	1 1/8
7/16	1 1/4
1/2	1 3/8
9/16	1 1/2
5/8	1 3/4
3/4	2
7/8	2 1/4
	2 1/2
	3

Other diameters on specification

TUBING

TYPICAL SIZES INCHES

O. D.	I. D.
3/8	1/4
1/2	3/8
3/4	1/2
1	3/4
1 1/2	1
2 1/2	1 1/2
3	1 3/4

HERE'S WHY: You can order in quantity and in a wide variety of sizes—and be certain of complete uniformity throughout. Our strict density control assures you thoroughly non-porous Teflon—free from any flaws which might possibly affect your end use or product. Dimensions are accurate to your most critical tolerances—no rejects, waste of material or loss of time. You get product purity—Teflon at its best in every one of its remarkable characteristics. Delivery is prompt—you get the quantity you want when you want it.

Since the availability of Teflon, "John Crane" engineers have worked with Industry to successfully solve innumerable problems and develop new applications. *You can benefit from their experience and know-how.*

Characteristics of Teflon

CHEMICAL
Completely inert.
ELECTRICAL
Very high dielectric strength.
Extremely low power factor.
THERMAL
Temperature range −300° to +500° F.
MECHANICAL
Strong, flexible, weather resistant.
LOW COEFFICIENT OF FRICTION
Absolutely non-stick.

* DuPont Trademark

Request full information and ask for our bulletin, "The Best in Teflon." Crane Packing Co., 1827 Belle Plaine Ave., Chicago 13, Ill. • In Canada: Crane Packing Co., Ltd., 617 Parkdale Avenue, N., Hamilton, Ont.

JOHN CRANE
CRANE PACKING COMPANY

For more information, turn to Reader Service Card, Circle No. 409

Contents Noted

Reports . . .

at low temperatures has bee studied experimentally.

Ozone and rubbers STUDY OF REACTION OF OZONE WITH POLYBUTADIENE RUBBERS. REPORT NO. 7 PERIOD 1 JUL. 1954 THRU 31 DEC 1954. *Augustana Research Foundation, Rock Island, Ill. Feb. 1955 48 pp. graphs, tables. Available from Library of Congress, Photoduplication Service, Publications Board Project, Washington 25, D. C. Mi $2.75, ph $6.50* PB117463

Moisture and insulating materials WET-COLD I: EFFECT OF MOISTURE ON TRANSFER OF HEAT THROUGH INSULATING MATERIALS. *Alan H. Woodcock and Thomas E. Dee, Jr. U. S. Climatic Research Laboratory, Lawrence, Mass. Dec. 1954. 24 pp graphs. Available from Office of Technical Services. U. S. Dept. of Commerce, Washington 25, D. C. 75 cents.* PB111639

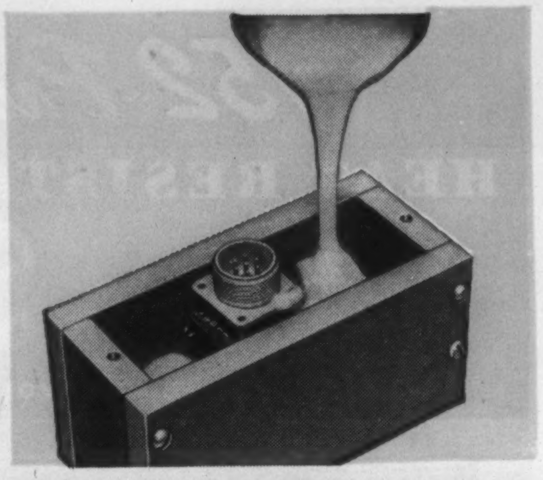
Using the basic principles of moisture diffusion and heat transfer, relations between rate of drying, rate of heat transfer, drying time and location of moisture have been derived. Representative computations have been made for completely wicking and completely non-wicking insulating materials. Textile materials with widely different wicking properties were then selected for study. The time course of heat transfer through each of these fabrics after wetting was then determined using a flat plate heated to 92 F in a constant temperature room at 30 F and a relative humidity of 75% ± 5%.

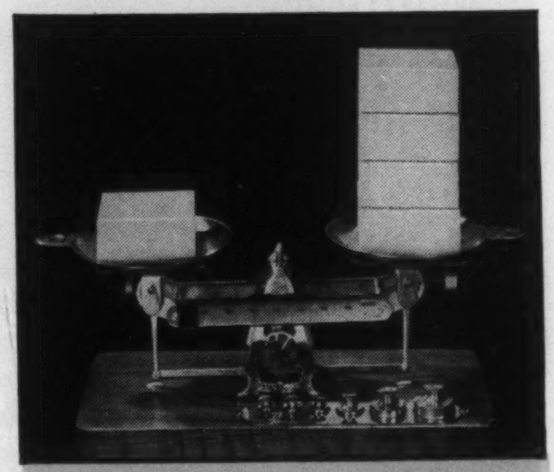
It's easy to obtain product data with the postage-free Reader Service Cards provided on pages 67 and 68. Use them for information on advertised products, too. Just circle the key number which appears at the bottom of the ad.

NOPCO® LOCKFOAM

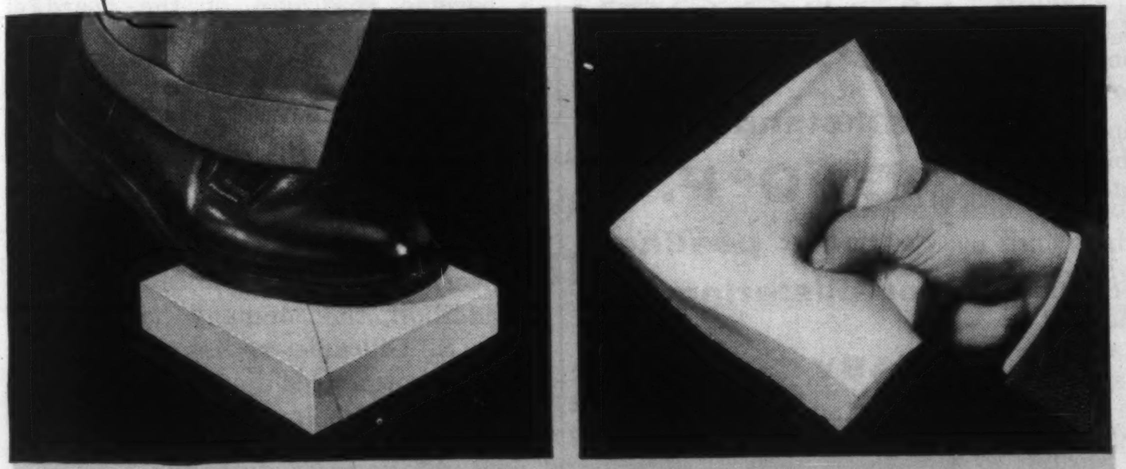
FOAMED PLASTIC

. . . that finds an important new function almost daily

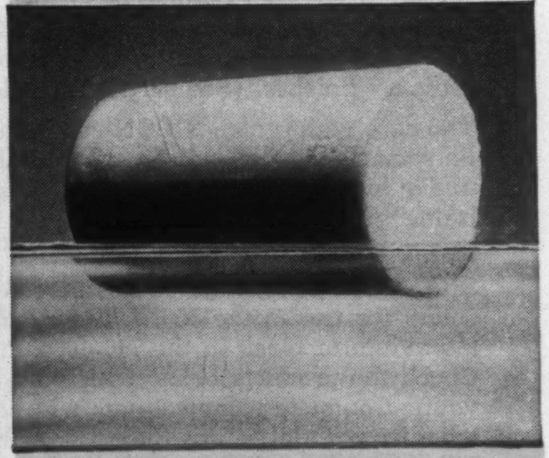




Choose your density



Rigid or flexible . . . as you like



Resists moisture

The properties we can't illustrate are at least as important as those we can

Near-perfect
Radar transmission

Ease of Fabrication
It's "poured-in-place"

Great Strength
with Light Weight

Wide Range of Densities
from 2 to 35 lb/cu ft

Good Thermal Insulation
"K" Factors
.018 at 8 lb/cu ft
to .025 at 11 lb/cu ft

Excellent Electrical Properties
6 lb/cu ft Lockfoam tested
at 9.375 KMC
Dielectric Constant 1.05
Loss Tangent .0005

Available in sheet form

Great versatility
50 different and
consistently reproducible
formulations available

A few of Nopco Lockfoam's present uses

Airplane Radomes, Potting Electronic Instruments, Reinforcing Automobile Doors, Automobile Arm Rests, Packaging, Shock Panelling, Instrument Cases, Insulating Water Coolers and Refrigerators, Cushioning, Walls for Portable Units, Buoys.

Our technical staff will give you every assistance in choosing among Lockfoam's 50 different formulations, and in making its economies *your* economies.

Write today for the Nopco Lockfoam booklet.

Nopco Chemical Company,
548 Stier St., Harrison, N. J.

NOPCO

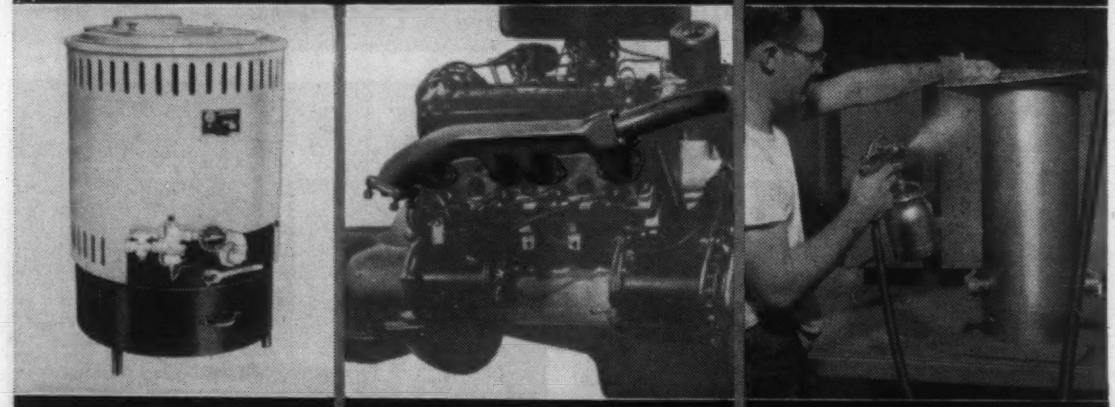
PLASTICS DIVISION

HARRISON, NEW JERSEY
Los Angeles, Calif.

• For more information, turn to Reader Service Card, Circle No. 464

152 Problems in
HEAT RESISTANT FINISHES
solved by Sicon

AMERICA'S FIRST AND FOREMOST SILICONE PROTECTIVE COATINGS



Smart SICON White for INCINERATORS. Protects up to 550°F.

SICON Black For Manifolds. Protects up to 1000°F.

SICON Aluminum for jet engines. Protects up to 1000°F.

Shown above are examples of 152 product finish applications successfully solved by SICON last year after high temperatures had decomposed ordinary finishes. (See partial list below.)

The ease with which SICON can be applied—its remarkable film adhesion and stability under high heat without peeling, blistering, or losing gloss—accounts for its high preference for these products.

SICON can be formulated in smart decorative colors for use in the 550°F. range, and in aluminum or black in the 750-1000°F. range. Check the products below which are similar to yours. Complete technical data will be sent, together with latest brochure of case histories. Fill out and mail today.

New Brochure of Case Examples Now Ready

Sicon withstands up to 1000°F. without peeling or blistering.

EASY TO APPLY by Brush, Spray or Dip

MIDLAND Industrial Finishes Co.
55 East Water Street, Waukegan, Illinois

Please send brochure and data for items checked, on SICON applications.

☐ Air Conditioning
☐ Aircraft Parts
☐ Appliances
☐ Arc Lamps, Spotlights
☐ Automotive Parts
☐ Boilers, Burners
☐ Chemical Equipment
☐ Control Systems
☐ Elect. Control
☐ Elect. Melting Pots
☐ Electronic Equipment
☐ Furnaces
☐ Gas Ranges
☐ Grilles
☐ Hardware
☐ Heaters
☐ Incinerators
☐ Metal Cabinets
☐ Mining Machinery
☐ Motor Bikes
☐ Name Plates
☐ Oil Burners
☐ Packaging Machinery
☐ Pumps
☐ Resistors
☐ Starters, Clutches
☐ Stoves
☐ Surgical Machines
☐ Thermometers
☐ Transformers
☐ Tubing, Steel Welded
☐ Turbo Dryers
☐ X-Ray Equipment

NAME ____________________
TITLE ____________________
FIRM ____________________
ADDRESS ____________________
CITY, ZONE AND STATE ____________________

For more information, turn to Reader Service Card, Circle No. 418

news of ENGINEERS COMPANIES SOCIETIES

News of Engineers

William M. Oliver has been appointed process development engineer, Acheson Colloids Co. Mr. Oliver replaces **Bart Dickey** who has been promoted to production manager.

Dr. Walter G. Driscoll has been made assistant director of research, Baird Associates, Inc. He will be in charge of the company's transistorized electronics department.

P. G. Weidner has been advanced to the position of plant manager, Capehart-Farnsworth Co., a division of International Telephone and Telegraph Corp.

James M. Darbaker has been elected president of Copperweld Steel Co. to succeed **Frank R. S. Kaplan** who has become chairman of the board of directors.

K. O. William Sandberg has been named manager of General Electric Co.'s Decatur, Ill., plastics plant, and **Henry E. Heddesheimer** has been made consultant on electrical engineering in the company's Plant Engineering and Maintenance Services. In addition, the company has assigned **J. S. Gillespie** as manager of the newly-organized diamond project section of Carboloy Department. In his new position, Mr. Gillespie will be responsible for transforming laboratory techniques of making man-made industrial diamonds into practical production methods.

Dr. Lawrence R. Hafstad, director of General Motors Corp.'s research staff, has been elected a vice president of the corporation.

Harvey Scott, Thomas S. Solomon and **Heinz Uelzmann** have joined the staff of The B. F. Goodrich Co. Research Center as research chemists. Other staff appointees include **Dr. Paul J. George,** senior technical man, **Peter R. Fatianow** and **Carl A. Stearns,** junior technical men, **Emin I. Arsan,** technical man, and **B. James Bailey,** technical man in the Physical Research Department.

J. C. Graden, formerly industrial products development engineer, Goodyear Tire and Rubber Co., has been made manager of technical service and design of industrial products at the Goodyear-Oxo factory near Mexico City.

(More News on p. 224)

Closeup of mandrel, Ampco-coated steel balls fill tube during bending, prevent walls from collapsing.

Completed bend in Pines Precision Bending Machine.

Pines Engineering
licks "impossible" job

. . . bends ultra-thin stainless tubing
. . . cuts airplane costs $14,000
***thanks to* AMPCO* METAL**

AIRCRAFT engineers said that cold bending of thin-wall tubing sections for engine and airframe components was impossible — that it couldn't be done. But Pines Engineering Co., Aurora, Illinois, went to work anyway. It developed a precision bending machine that makes smooth, sharp bends to 10″ centerline radius in up to 5″ diameter x .025″ wall stainless tubing — bends that are cutting airplane costs up to $14,000 each.

Pines selected Ampco Grade 20 wiper dies and Ampco-coated mandrels for their new precision machine to resist the tremendous pressures developed in this bending operation. Here's what they say:

"Ampco eliminates the problem of pickup on the mandrel and wiper die when bending stainless steel tubing. And Ampco provides a hard-wearing surface that enables the production of thousands of bends before dies have to be refitted."

And if you draw, form, or bend stainless, pickled carbon steel — or many other metals — here's what *you* get with Ampco dies:

Little or no pickup. You eliminate all the expense of redressing steel dies — redressing that is necessary because of scratching, galling, or pickup. Idle time is cut — and your line keeps moving at top production.

Low finishing costs. You end galling, loading, scratching, die marks. No more problems with big scrap losses. You reduce expensive finishing time.

This remarkable copper-base alloy pays off on your drawing or forming line with longer life, lower costs, less operating grief. Get all the facts on cost-saving Ampco dies from your nearby Ampco field engineer or mail the coupon.

Tear out this coupon and Mail Today!

LET AMPCO PROVE ITS ~~METAL~~ mettle

AMPCO®
Sole producer of genuine Ampco Metal

Ampco Metal, Inc.
MILWAUKEE 46, WISCONSIN
West Coast Plant • Burbank, California

*Reg. U. S. Pat. Off.

Ampco Metal, Inc., Dept. MA-11, Milwaukee 46, Wisconsin

I'd like to know more about time- and money-saving Ampco dies. Please send me more information.

Name.. Title....................

Company..

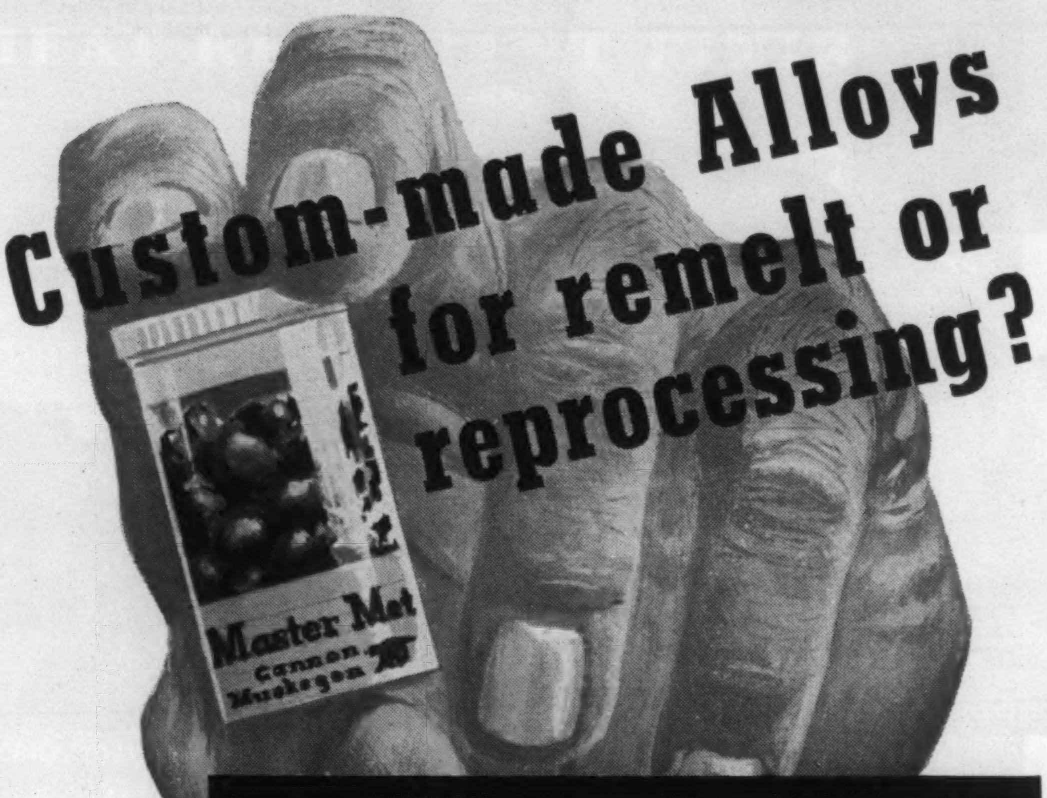
Company Address..

City.. (..........) State....................

D-39A

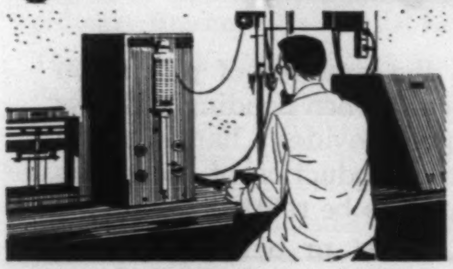
For more information, turn to Reader Service Card, Circle No. 470

Need pounds or tons of

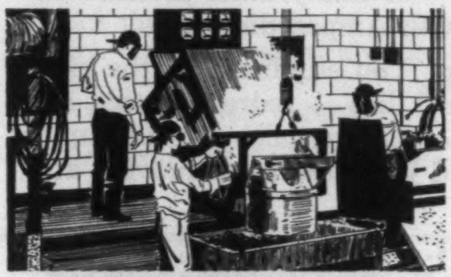


Custom-made Alloys for remelt or reprocessing?
Master Met
Cannon
Muskegon

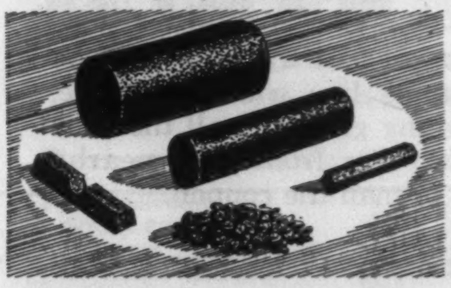
Call on Cannon-Muskegon



Heats checked for chemical analysis.



High frequency induction furnaces.



Carried in stock are supplies of the 300 and 400 stainless steels as well as carbon alloys. "Specials" including electronic and aeronautical type alloys, tool steels, ferritic, austenitic and super stainless alloys of nickel- and cobalt-base. Available in shot, ingot, billet or cast bars.

Exactly predictable metallurgical control of finished casting is assured by MasterMet control of high-temp alloys, tool, stainless, and carbon steels

You specify the alloy — we'll tailor it to your needs, backed by a *certified* analysis! Name the quantity and the fast delivery will surprise you! Preparation can begin almost immediately after receipt of order. MasterMet "alloy tailoring" gives you all this:

MATCHED ALLOYS TO YOUR MELTING PROGRAM—Close control assures a constantly uniform melt. The results you get from a sample cast are the same as the final production run.

MASTERMET CERTIFIED ANALYSIS—Regularly furnished are notarized certificates insuring alloys that will cast to your exact production specifications.

PRODUCTION MELTS OR SAMPLE JOBS — A combination of test furnaces and larger multiple production furnaces assure completely flexible service at any time.

FAST ACTION ON YOUR ORDERS — No long delays for a mill run. Alloys delivered in drums, clearly marked with all specifications for fast selection and storage.

Write today for your copy of new MasterMet Alloy Bulletin for complete technical details.

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Muskegon
CORPORATION
MASTERMET
2873 Lincoln Street • Muskegon, Michigan

METALLURGICAL SPECIALISTS

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news of | ENGINEERS

Henry J. Conroy has been appointed technical consultant in rubber research, Armour Research Foundation of Illinois Institute of Technology. In addition, the Foundation has designated **Vincent J. Cushing** as manager of the Propulsion and Structural Research Department.

Theodore F. Smith has joined Kaiser Engineers Div., Henry J. Kaiser Co., as industry consultant.

Herbert H. Schroeder, Jr., has augmented the staff of Lithium Corp. of America, Inc., as coordinator in the new Product Research & Development Department.

N. P. Synnestvedt has been made plant manager and **J. G. Maurer,** shop superintendent, Manistee Iron Works, division of Michigan Tool Co.

C. L. Peterson has been appointed vice president and general manager, Brown Instruments Div., Minneapolis-Honeywell Regulator Co.

John P. Borda has been named general manager of National Lead Co.'s Magnus Metal Div., and **Edward M. Van Winkle** has become president of Magnus Metal Corp., a subsidiary of National Lead Co. Both positions had been held by **William V. Burley,** also a vice-president of National Lead, who has retired after 33 years of company service.

Professor Norman N. Barish has been made chairman of the Department of Industrial and Management Engineering, New York University College of Engineering.

John E. Hawley has been transferred to the Technical Service Department of Pennsylvania Salt Manufacturing Co.'s Chemical Specialties Div. as a technical service engineer.

Dr. Robert Maddin has been made professor of metallurgical engineering, **Dr. Saul Gorn** and **George W. Patterson, III,** associate professors of electrical engineering, and **Dr. Friedrich H. Effertz,** assistant professor of electrical engineering, University of Pennsylvania.

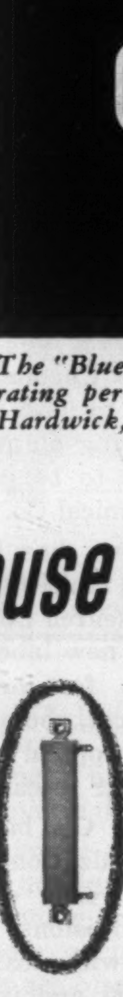
Paul H. Hoffman, vice president, Spun Lite Corp., has been selected to head the firm's research activities and direct the development of new products and manufacturing processes.

William N. Rathbun, formerly chief industrial engineer, Temco Aircraft Corp., has been given the new position of plant facilities engineer for the firm. **James F. Parrish** was ele-

New Resistor Stands Higher Overloads... Without Crazing!

The "Blue Ribbon", resistor with a higher wattage rating per unit space requirement. Made by Hardwick, Hindle, Inc., Newark, N. J.

because of DRIVER-HARRIS 146 ALLOY



Here is a resistor really new and different . . . the compact Hardwick, Hindle "Blue Ribbon," which stands remarkably high overloads and excessive heat without crazing.

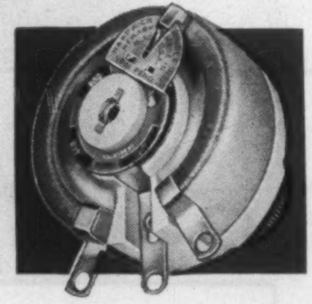
Special design features which make this possible are: an aluminum thru-bar extending through the center of the elliptical ceramic core, which insures a more even distribution of heat to prevent "hot-spots;" and a thermo-shock-proof enamel coating which eliminates crazing.

Heretofore, crazing, which occurred mostly at *terminal* areas, shortened resistor life and limited the safety factor. To prevent this, an alloy with three hard-to-find qualities was needed: (1) It had to have a coefficient of expansion to match all integral parts; (2) it had to be free of gas; (3) it had to form a perfect bond with the enamel.

A large order, indeed. But Driver-Harris filled it by developing #146, a glass-to-metal sealing Alloy. This alloy now makes it possible to operate resistors and rheostats at hitherto dangerous overloads, with no risk of breakdowns in the enamel coatings.

146 Alloy is one of 4 Driver-Harris Alloys which cover most glass-to-metal sealing needs—available as rod, wire, strip, sheet foil, and in special shapes. Today the makers of the "Blue Ribbon" use 146 Alloy for the terminals in all of their resistors and rheostats as well. They also use Nichrome*, Advance*, and other gas-free resistance alloys made by Driver-Harris in winding the cores.

What you can learn from this is clear. If you also need a special purpose alloy, send us your specifications. Our engineers with 48 years of experience are at your service.



One of a new line of "H" Series high wattage rheostats made by Hardwick, Hindle, using Driver-Harris Alloys.

*T. M. Reg. U. S. Pat. Off.

Nichrome and Nichrome V are made only by

SPECIAL PURPOSE ALLOYS SINCE 1899 D/H TRADE MARK REG. U. S. PAT. OFF.

Driver-Harris Company HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Louisville, Los Angeles, San Francisco

In Canada: The B. GREENING WIRE COMPANY, Ltd., Hamilton, Ontario

MAKERS OF THE MOST COMPLETE LINE OF ELECTRIC HEATING, RESISTANCE, AND ELECTRONIC ALLOYS IN THE WORLD

For more information, turn to Reader Service Card, Circle No. 476

SPECIALISTS IN STAINLESS STEEL TUBING

Jumping thru a hoop for you ...is our business!
FORMED STEEL TUBE INSTITUTE
FSTI

● When you want such information as delivery, price and other details on an inquiry or order, you want it quickly. Damascus makes a point of quoting the same day. Many times a "same-day" quote means literally jumping through a hoop. But, good service is a sound way to obtain going business, so we give good service. Phone, wire or write Damascus about your stainless steel tubing needs for same-day quote.

Ask us... DAMASCUS

DAMASCUS TUBE COMPANY
STAINLESS STEEL TUBING AND PIPE
Greenville, Pennsylvania

For more information, turn to Reader Service Card, Circle No. 417

news of | ENGINEERS

vated from general supervisor to succeed Mr. Rathbun as chief industrial engineer.

Ralph W. Updegraff has been promoted to chief industrial engineer, The Timken Roller Bearing Co. The company also promoted **Ross Russell** to the post of divisional industrial engineer for the Steel and Tube Div.

Dr. Alvin M. Weinberg has been named director of Oak Ridge National Laboratory.

William L. Batten has been advanced to manager of Vanadium-Alloys Steel Co.'s Powder Metallurgy Department, and **Dr. John C. Hamaker** has been promoted to manager of the Research Department to head the company's continuing research on new alloy tool steel development.

news of | COMPANIES

Expansions planned

The Borden Co.'s Chemical Div. has announced plans to build a synthetic resin manufacturing plant in Manila. The operation is to be incorporated as the Casco Chemical Co.

Borg-Warner Corp. has begun construction of a multi-million-dollar Borg-Warner Research Center in Des Plaines, Ill. The new laboratory will contain facilities for metallurgical, electronic, electrical, chemical, acoustical, hydraulic, applied mechanical, physics and nuclear research.

Copperweld Steel Co. has disclosed plans for a modernization and expansion program at each of its main manufacturing divisions. The complete program will cost approximately $12,000,000 and is scheduled for completion in 1957.

The **Dow Chemical Co.** has begun construction of a new plant in Torrance, Calif., for the manufacture of Styrofoam, an expanded, lightweight, multicellular plastic.

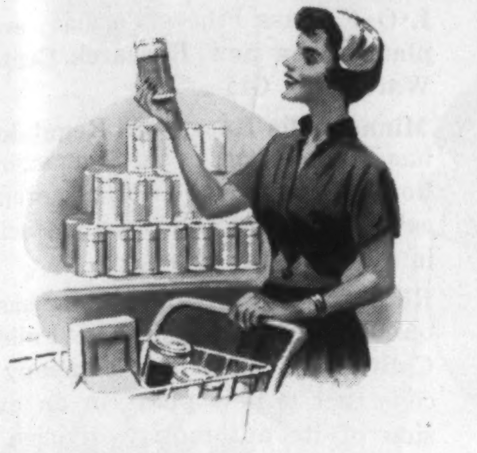
Gulf Oil Corp. recently announced plans for a nuclear science laboratory to be located at the company's research center in Harmarville, Pa.

Harvey Machine Co., Inc., and **Harvey Aluminum** have disclosed that construction of the reduction plant at The Dalles, Ore., will begin early in 1956.

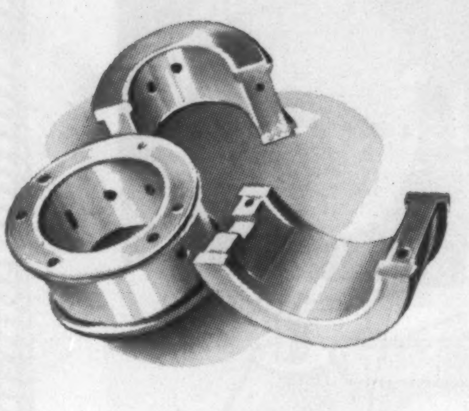
Holiday Plastics Inc. has leased new production facilities at 1301 Fairfax Trafficway, Kansas City, Kans.

(More News on p. 228)

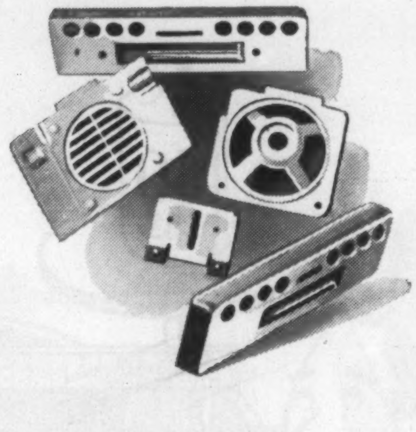
New uses for STRAITS TIN from MALAYA improve products—cut costs



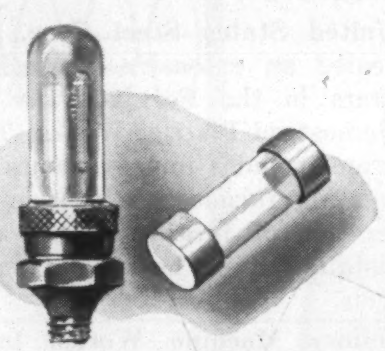
Soft drinks, quinine water—even wine—now go to market in handy disposable tin cans.



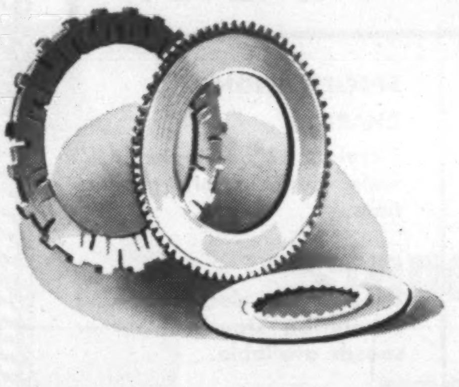
These new tin-aluminum bearings (up to 30% tin) are several times stronger than babbitt.



Tests show that a new tin-zinc plating alloy gives unusual corrosion protection to steel.



A new solder of tin and indium is being used to join glass to metal and metal to ceramics.



Tin is an important component of many sintered metal parts, such as these clutch facings.

And organotin compounds are the best stabilizers known for polyvinyl chloride plastics.

These are just six of hundreds of new ways Straits Tin is being used today. No other metal has tin's capacity for making other materials more efficient.

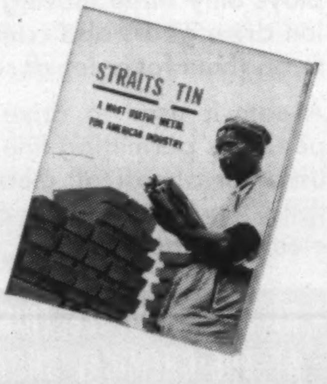
For example—

A tin coating on the fin coils of air-conditioning units helps prevent corrosion and odor accumulation. Modern engine pistons are often plated with tin to reduce friction between the piston and the cylinder liner. And a new way of electroplating bright tin-nickel offers for the first time a successful alternate to chrome on nickel-copper. Tin-nickel is both more corrosion resistant and more attractive than chrome. And it helps save scarce nickel.

Tin, of course, is not scarce. Nor is it likely to be in the future. Over one-third of the world's tin comes from Malaya. A great deal is there. And Malayan tin producers want to export it as much as American industry wants to use it.

Malaya is the keystone of Southeast Asia. With Malaya steadily winning its war against Communist guerrillas—with the new Manila Treaty and new U.S. Economic Aid Plans promising increased security against Communist infiltration in this vitally important area—American industry can count on a supply of tin fully as dependable as the supplies of other materials that are being produced in the Free World.

Straits Tin from Malaya is at least 99.87% pure—has been recognized as a standard grade for years. It is inert, nontoxic, friction and corrosion resistant. It is highly malleable, wets metals readily, and has a relatively low melting point (450°F.). Whatever your product or process may be, a careful reappraisal of the properties of Straits Tin may show you new ways to raise quality and lower costs.



A 20-page new booklet gives an informative report on Straits Tin and its many new uses today. Write for a free copy now.

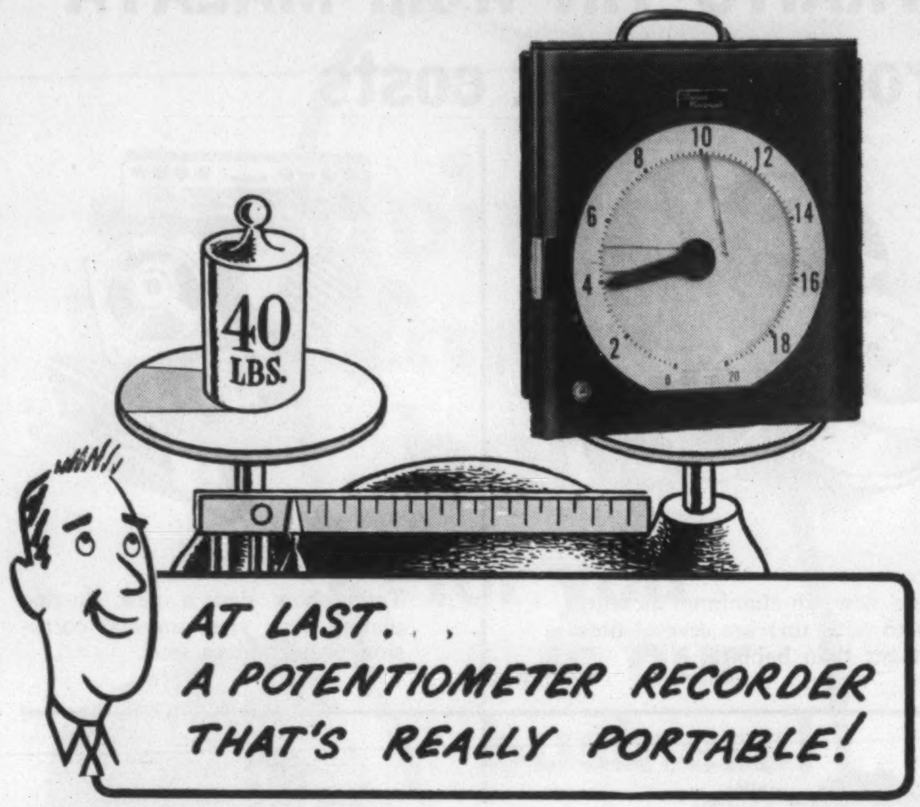
Since February 1953, there have been no restrictions by the U.S. Government on the use of tin

MALAYAN TIN BUREAU

The Malayan Tin Bureau

Dept. 24-L, 1028 Connecticut Ave., Washington 6, D. C.

For more information, turn to Reader Service Card, Circle No. 343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A POTENTIOMETER RECORDER
THAT'S REALLY PORTABLE!

In response to the increasing demand in industry for a truly portable indicating recorder, we have redesigned our standard Thermo Electronic Recorder . . . making it 18 lbs. lighter . . . without sacrificing either accuracy, sensitivity or durability.

In addition to recording temperatures in 19 standard ranges, from —100° to +100°F. up to 0° to 3000°F., it is also used to measure humidity, solution conductivity, speed, pH, direct current, DC voltage, power, strain, or any other measurement that can be converted to a change in resistance or DC millivoltage.

The simple design of the electronic balancing system of this instrument employs only three moving parts, and nylon drive gears and cam rolls are used throughout for quiet, durable operation.

A cam is used to drive the recording pen, thus permitting linear charts to be used for almost all measurements, despite the non-linearity of the sensitive element characteristics.

SPECIFICATIONS

CHART
Circular, 12" diameter, 4⅝" scale width, uniform graduations.

CHART DRIVE
Synchronous, electric, 24-hour revolution standard, other speeds available.

CALIBRATION ACCURACY
±¼ of 1% of scale span.

BALANCE CONTROL ACTION
Continuous null, positive drive of slidewire and pen, no galvanometer, unaffected by vibration.

SENSITIVITY
One slidewire turn (less than ±1/20 of 1% of scale).

DIMENSIONS
16⅞" wide by 18⅜" high by 7½" deep.

NET WEIGHT
40 lbs.

BE SURE AND SEE THIS NEW EQUIPMENT AT THE CHEMICAL SHOW IN COMMERCIAL MUSEUM, PHILA., IN BOOTH C156-158!

. . . or write for catalog Section 60-100 covering this latest addition to the growing T-E line.

We have openings for qualified sales engineers and design engineers with electro-mechanical or instrument experience. Include resume with letter of application. Salary commensurate with experience.

Pyrometers • Temperature Monitoring Systems • Thermocouples • Protection Tubes
Quick-Coupling Connectors and Panels • Thermocouple and Extension Wires

Thermo Electric Co., Inc.
SADDLE RIVER TOWNSHIP, ROCHELLE PARK POST OFFICE, NEW JERSEY
IN CANADA—THERMO ELECTRIC (Canada) Ltd., BRAMPTON, ONTARIO

For more information, turn to Reader Service Card, Circle No. 415

news of COMPANIES

L·O·F Glass Fibers Co. has revealed plans for a new Research Center at Waterville, Ohio.

Minneapolis-Honeywell Regulator Co has commenced a three-quarter-million-dollar expansion of its aeronautical engineering and research facilities in Minneapolis.

Rheem Manufacturing Co. has acquired a 59-acre site in Fullerton, Calif., on which the company will construct a new plant in an expansion of its automotive division. The property was purchased by Rheem Acceptance Corp., an affiliate of the parent organization, and will be leased to Rheem Automotive Co., formerly known as U. S. Spring & Bumper Co.

United States Steel Corp. has revealed an extensive expansion program in the Forgings Div. of the Homestead District Works. The program includes improvements in heat treating furnaces, relocation and alteration of forging presses and the installation of heavy duty machine tools.

Zollner Machine Works, Inc., has completed plans for construction of a permanent mold aluminum foundry.

Mergers, acquisitions

American - Marietta Co. has purchased **Stoner-Mudge, Inc.** The acquisition broadens American-Marietta's position in the field of coatings for lining cans.

The Budd Co. has revealed that it will manufacture, sell and service the gamma radiography equipment and sources previously produced by **The Gamma Corp.**

Electro Refractories & Abrasives Corp. has purchased a substantial interest in **Spar-Mica Corp.** of Montreal, Canada, as a diversification move into the field of ceramic and other nonmetallic materials.

Ferro Corp. has announced the merger of two of its subsidiaries, The **Louthan Manufacturing Co.** with **Ferro Powdered Metals, Inc.** The merged company will carry on both operations under the name of The Louthan Manufacturing Co.; however, Ferro Powdered Metals will be known as the company's Ferro Powdered Metals Div.

Hoskins Manufacturing Co. has formed Hoskins Alloys of Canada, Ltd., as a wholly-owned subsidiary and has purchased the complete wire drawing division of **Walker Metal**

standard for comparison

...and with high speed steels the standard is REX

Living up to a standard for comparison isn't easy. That's why Crucible lavishes special care on the manufacture of REX® high speed steels...to keep REX the *standard* wherever high speed steels are used—as it has been for over half a century.

It's easy to *prove* the superiority of REX. Use it on the job...check its size, structure, response to heat treatment, fine tool performance. You'll agree with thousands of other users—*you can't find a high speed steel to outperform REX.*

Remember, REX is made only by Crucible. So call for REX at any Crucible warehouse, or for quick mill delivery. *Crucible Steel Company of America, Henry W. Oliver Building, Pittsburgh 30, Pa.*

CRUCIBLE **first name in special purpose steels**

Crucible Steel Company of America

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NEW! BAUSCH & LOMB WIDE FIELD MACROSCOPES 10X to 40X

Handy 'scopes spot-check production, speed small parts work

Use it in tripod...
in microscope stand...
... or even built into machinery!

- Actual size as shown here ... compact, handy
- Shows natural right-side-up views... easier for inexperienced users... a big help in precision assembly!

Just grab this dependable inspection aid for on-the-spot checks of work and materials in any phase of production. Available with folding tripod or sturdy microscope stand, for detailed study and for small-parts assembly. You can even build it right into production machinery!

Upright images are sharp and detailed to the very edge of the extremely wide field of view. Long working distance makes it easy to manipulate specimens ... gives operators plenty of room for precision assembly and repairs. (Also available as straight tube for applications where upright image is not required.)

FREE DATA BULLETIN!
ON-THE-JOB DEMONSTRATION!

Find out how this inexpensive production tool can lower your manufacturing costs. WRITE, WIRE or PHONE today for free demonstrations and Data Bulletin D1052. Bausch & Lomb Optical Co., 79347 St. Paul St., Rochester 2, N. Y. (Phone: LOcust 3000).

BAUSCH & LOMB
SINCE 1853

AMERICA'S ONLY COMPLETE OPTICAL SOURCE
... FROM GLASS TO FINISHED PRODUCT

Products, Ltd., Windsor, Ontario. The new Canadian subsidiary will occupy modern plant facilities now being built in the metropolitan Toronto area, and will also take over operation of the newly-acquired wire drawing facilities.

Kaiser Aluminum & Chemical Corp. has completed purchase of the aluminum extrusion plant at Halethorpe, Md., from the General Services Administration. Kaiser Aluminum had been operating the plant since 1951 under the terms of a lease with the agency.

Sperry Products, Inc., has acquired **Western Inspection, Inc.** Western Inspection will become Sperry Western, Inc.

United-Carr Fastener Corp. has acquired two California companies which will operate a division of United-Carr subsidiary companies. **Graphik-Circuits** has become a division of **Cinch Manufacturing Corp.,** and **Plastic Process Co.** will be operated as a division of **Monadnock Mills.**

Walworth Co. has announced the acquisition of the assets and business of **Alloy Steel Products Co., Inc.,** and the **Southwest Fabricating & Welding Co., Inc.** Both firms will be operated as subsidiaries of Walworth.

New plants, new addresses

Biddle Screw Products Co., Sheridan, Ind., recently announced the completion of a plant expansion program involving more than a quarter of a million dollars.

Hooker Electrochemical Co.'s Durez Plastics Div. has brought into production a new $5,000,000 plant at Kenton, Ohio.

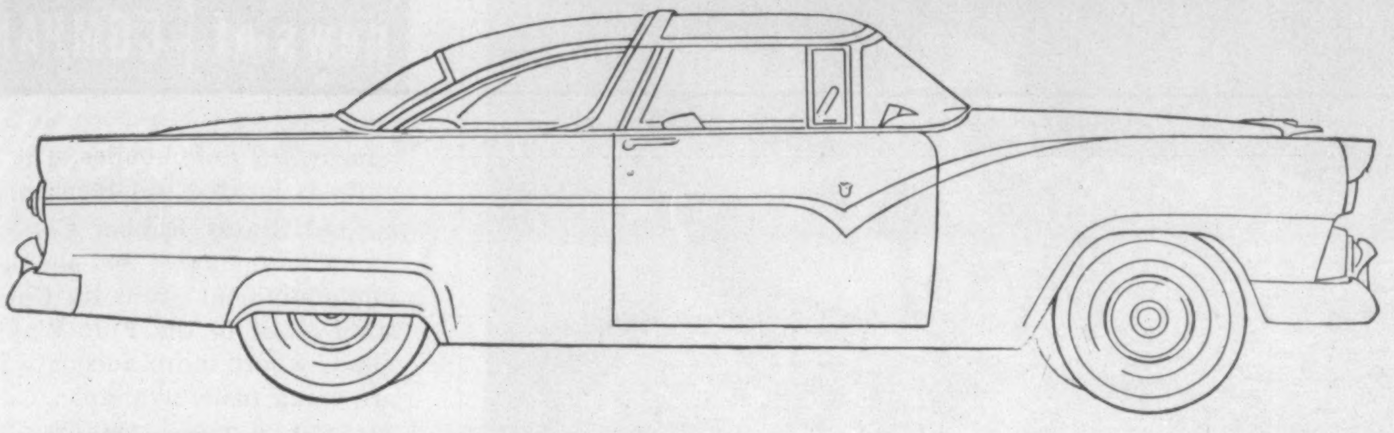
Hubbell Metals Inc. has announced the opening of a plant at 484 S. Front St., Memphis, Tenn.

Industrial Vinyls Inc. has opened a plant at 5511 N. W. 37th Ave., Miami, Fla.

Klem Chemicals, Inc., of Dearborn, Mich., has announced the opening of Klem Chemicals, Inc., of Calif., located at 1905 N. Central Ave., El Monte, Calif.

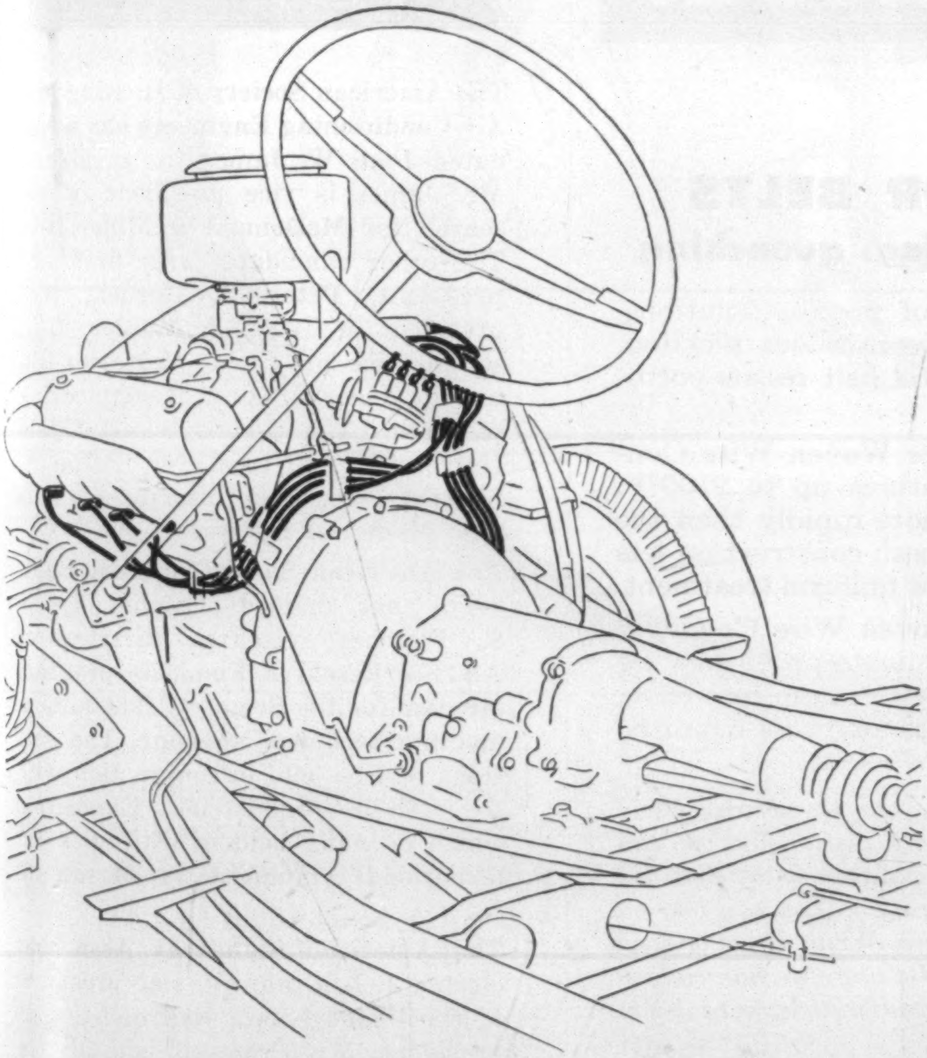
Metalphoto Corp. has moved into larger facilities at 6811 Superior Ave., Cleveland, Ohio.

Pittsburgh Plate Glass Co. has placed in production a plant specially designed to produce windshields for



Under the hood of the smart new Ford . . .

Neoprene protects ignition wire and spark plugs against moisture . . . resists ozone, heat and oil



Designers made sure the smart-looking 1955 Ford would be off to a fast start in any weather. On both the "Six" and the "Eight" they chose spark-plug covers and ignition-wire jackets made with neoprene for positive protection against moisture and deterioration.

Neoprene covers prevent seepage of moisture to the spark plugs . . . provide instant, all-weather action. And the sturdy neoprene jacket on the ignition wire protects the insulation against heat and oil.

Moreover, neoprene stays on the job . . . has what it takes to give long, dependable service. It resists ozone and other effects of corona discharge . . . remains firm and strong despite heat, oil and grease . . . won't chip, crack or soften.

Each year finds more automotive parts and accessories made with neoprene, Du Pont's chemical rubber. Because it stands up where ordinary resilient materials fail, neoprene is first choice among designers for key parts that improve performance . . . rarely need replacement.

Free! The Neoprene Notebook

Each issue shows you how designers created new products...improved old ones with neoprene. Actual case histories give you all the facts. Mail coupon below to get on mailing list.

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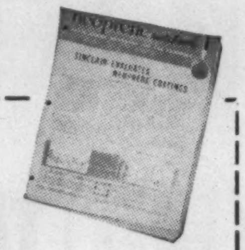

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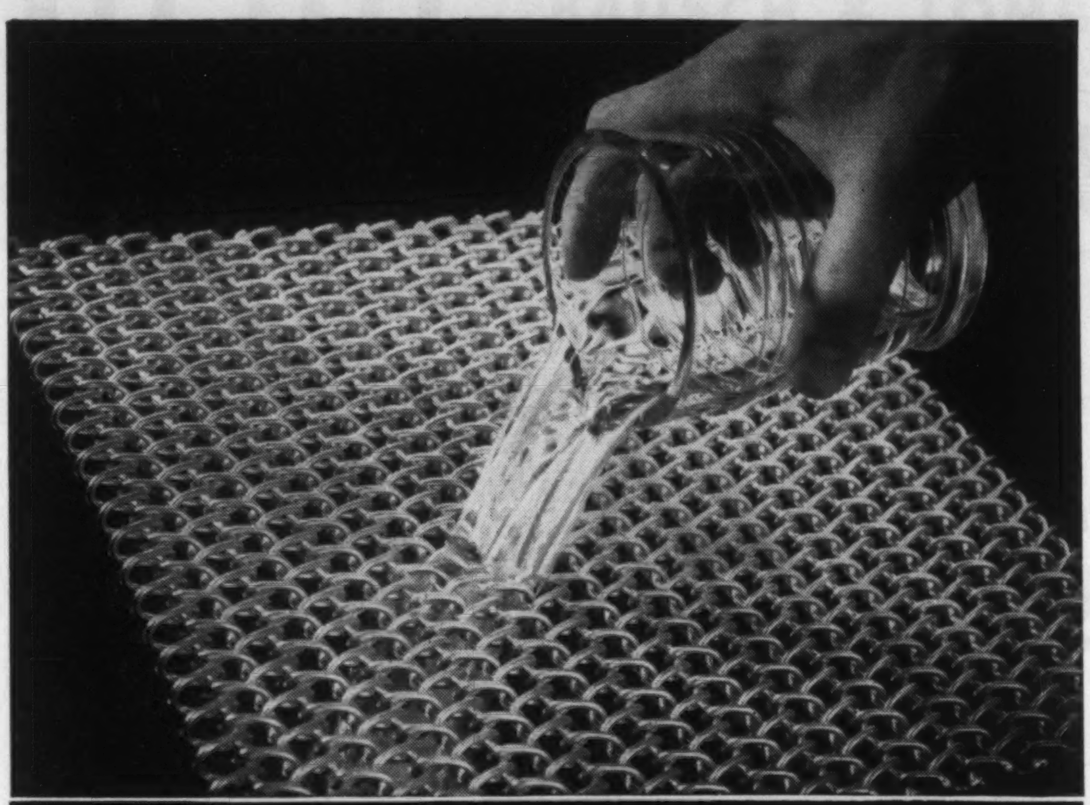

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WOVEN WIRE CONVEYOR BELTS

permit continuous washing, degreasing, quenching

Open mesh construction permits rapid drainage of process solutions, moving belt eliminates batch handling to provide continuous pickling, quenching, tempering, washing, degreasing. All-metal belt resists corrosion even under the most severe conditions.

In continuous heat treating installations Cambridge Woven Wire Conveyor Belts are impervious to damage at temperatures up to 2100°F. They have no seams, lacers or fasteners to wear more rapidly than the body of the belt . . . no localized weakening. Open mesh construction lets heat and gases circulate freely all around the work for uniform treatment.

No matter how you look at it, CAMBRIDGE Woven Wire Conveyor Belts are invaluable aids to AUTOMATION . . . eliminate profit-stealing batch and hand operations. They are made in any size, mesh or weave, and from any metal or alloy. Special raised edges or cross-mounted flights are available to hold your product during movement.

Here's how a Cambridge belt permits CONTINUOUS WASHING. Stamping and drawing compounds, and metallic particles are washed through open mesh.

Call in your Cambridge Field Engineer to discuss how you can cut processing costs by continuous operation. You can rely on his advice. Write direct or look under "Belting, Mechanical" in your classified telephone book.

ASK FOR FREE 130-PAGE REFERENCE MANUAL illustrating and describing woven wire conveyor belts. Gives mesh specifications, design information and metallurgical data.

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CONVEYOR BELTS

The Cambridge Wire Cloth Co.

WIRE CLOTH | METAL CONVEYOR BELTS | SPECIAL METAL FABRICATIONS

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OFFICES IN PRINCIPAL INDUSTRIAL CITIES

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news of | COMPANIES

noncurrent automobiles. The new facility is located in Greensburg, Pa.

United States Rubber Co. has completed transfer of its plastics molding equipment from its Chicago die mold plant to the Fort Wayne, Ind., plant, where more adequate facilities are being made available.

The Yale & Towne Manufacturing Co. has purchased a new plant at Addison, Ill., to be added to the facilities of its Powdered Metal Products Div. The newly-acquired plant will be principally devoted to the production of ferrite components used by the manufacturers of radio, television and other electronic equipment.

news of | SOCIETIES

The **American Society of Heating and Air-Conditioning Engineers** has nominated John W. James for president. Mr. James is vice president of research for McDonnell & Miller, Inc. The other candidates are: first vice president, Peter B. Gordon, vice president of Wolff & Munier, Inc.; second vice president, Professor Elmer R. Queer, director of engineering research, The Pennsylvania State University; and treasurer, Ralph A. Sherman, assistant director of Battelle Memorial Institute.

The **American Society of Tool Engineers** has named Colonel Leslie S. Fletcher, research director of ASTE's Research Fund, as program director for the Society's 1956 annual meeting technical sessions. The sessions will be held in conjunction with the ASTE Industrial Exposition which is being held in Chicago's International Amphitheatre, March 19-23.

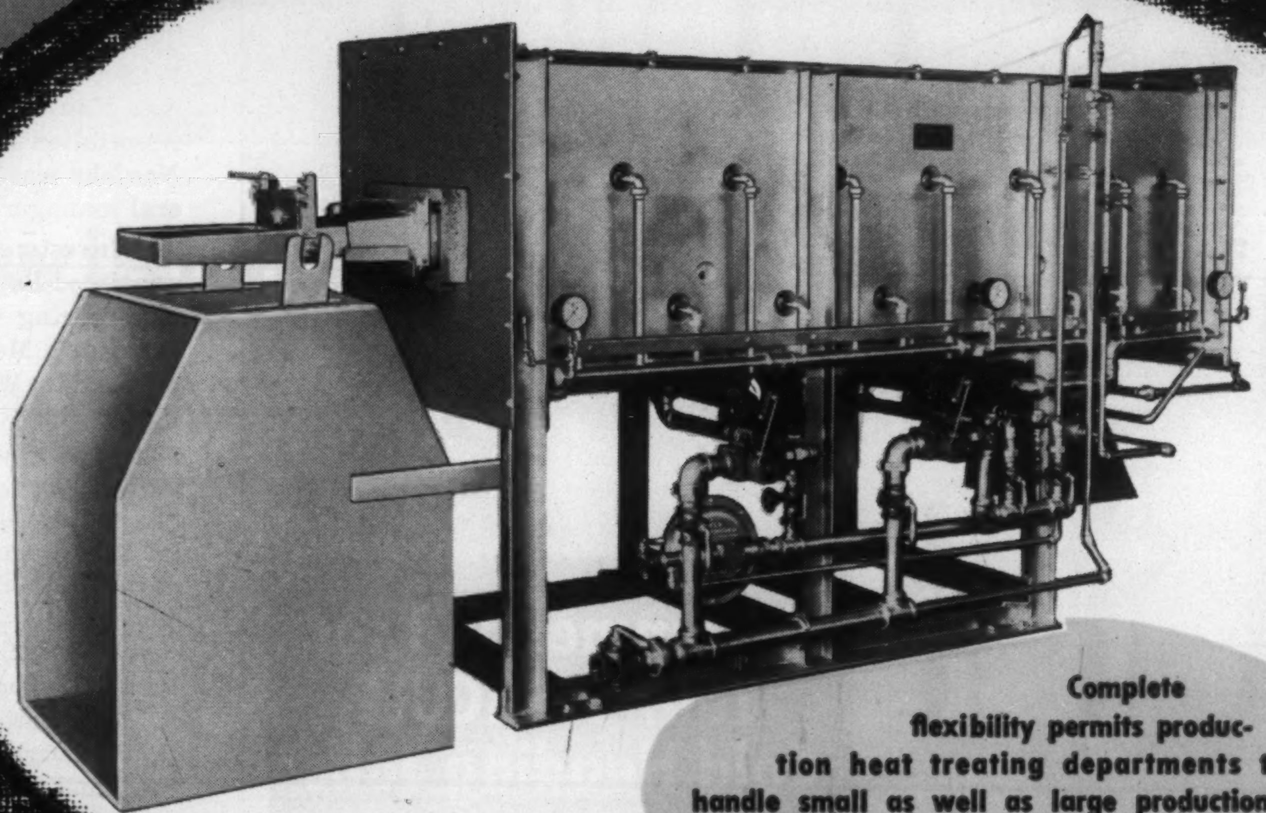
The **American Standards Assn.** has elected J. L. Cranwell, vice president of the Pennsylvania Railroad Co., as president. Mr. Cranwell will fill the post left vacant by the death of Edward T. Gushée, vice president of the Detroit Edison Co.

The **American Welding Society** has selected an article entitled, "Welding Faces Automation," by Monroe Edwards as the best student paper on welding to appear in an undergraduate publication during the year ending June 1, 1955. The author of the paper, who is a student at Georgia Institute of Technology, has received a cash award of $200. *The Georgia*

New RECIPROCATING HEARTH FURNACE

Patent 2,671,654

by AGF Pioneers, the originators and builders of Reciprocating Furnaces since 1921. Features include stationary muffle and complete atmosphere control.



Complete flexibility permits production heat treating departments to handle small as well as large production lots on a continuous basis.

Carburizing, case hardening, Ni-Carb process of ammonia-gas carburizing, clean hardening, etc. of parts ranging from balls for ball point pens to heavy forgings can be accomplished with ease in the same model without any modification.

Newly engineered fully automatic feeding device is now available to eliminate costly work handling in charging the furnace.

Individualized treatment assures uniformity of product. Each piece is individually heated, subjected to the atmosphere and quenched. Disadvantages of batch heating and quenching are eliminated. Work can be observed throughout the processing cycle.

Only the work enters and leaves the heating chamber. Baskets, trays, chains and other troublesome mechanisms are completely eliminated.

Sizes in production capacities up to 600 pounds per hour.
Representatives in principal cities.

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Send your Bulletin 850 which will help us produce a quality product at lowest cost.

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KEYSTONE
"SPECIAL PROCESSED"
COLD HEADING WIRE

Recommended for Your DIFFICULT Cold Heading Jobs

When you have "tough-to-make" cold heading jobs on your production schedule, it will pay you to consider the outstanding advantages offered by Keystone "Special Processed" Wire.

The superior grain flow characteristics of this wire provides the necessary upsetting and die forming qualities to withstand the terrific displacement of metal during the most difficult cold heading process. The structural soundness and uniformity of "Special Processed" Wire further proves itself through trouble-free machine operation, longer die life, and finished products of the highest quality.

If you have a special wire problem . . . large or small . . . let us help you solve it. Contact your Keystone representative or write.

Keystone Steel & Wire Company
Peoria 7, Illinois
Industrial Wire Specialists

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news of | SOCIETIES

Tech Engineer, which published the article in its May, 1955, issue, also received $200.

A second prize of $100 went to William J. Gress of the University of Florida for his article, "Welding, A Way of Thinking." The article appeared in the May, 1955, issue of *Florida Engineer*, and that student magazine received $100 for publishing the prize-winning entry.

The **Drop Forging Assn.** has announced the appointment of Waldemar Naujoks to its staff to head the Association's statistical program. Mr. Naujoks was vice president and general manager of Globe Forge, Inc.

The **Investment Casting Institute** has appointed Roger Waindle of Wai-Met Engineering Co. as chairman of the Institute's Metal Specifications Committee. Mr. Waindle succeeds Charles Yaker who has been chairman for the past two years. In addition, the Institute has selected George Cannon, Jr., of Cannon-Muskegon Co. to head its new Educational Program Committee. Other members of the committee will include David Veit, *Precision Metal Molding* magazine, K. M. Bartless, Thompson Products, Inc., R. R. Miller, Precision Metalsmiths, V. S. Lazzara, Casting Engineers, Inc., and Charles Schwartz, Misco Precision Casting Co.

The National Electrical Manufacturers Assn. has announced the election of ten more electrical manufacturers to membership. The new members are: Acme Battery Corp., Anderlab, Inc., Bright Star Industries, Burgess Battery Co., General Dry Batteries, Inc., Hill Transformer Co., Inc., Marathon Battery Co., Olin Mathieson Chemical Corp., Ray-O-Vac Co. and United States Electric Mfg. Corp.

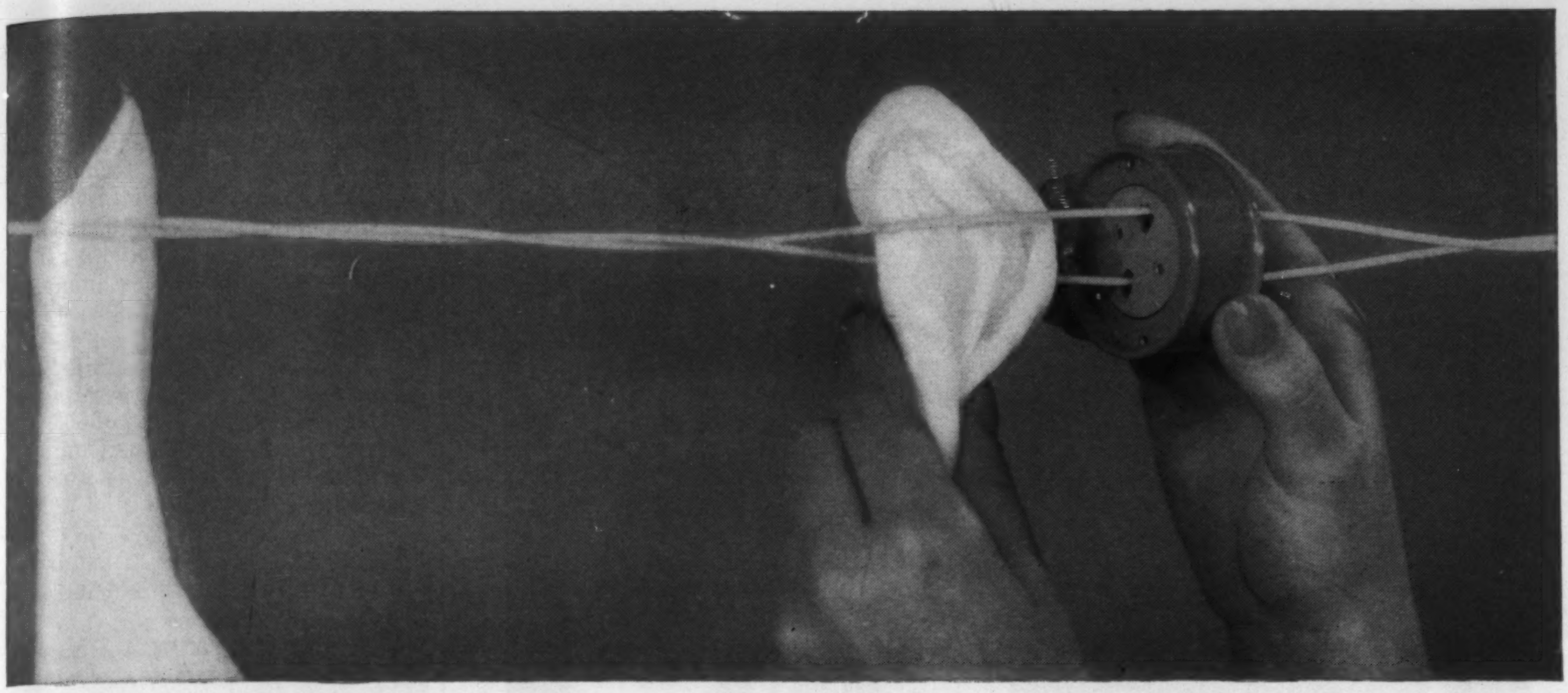
The Society of Industrial Designers has voted to change its name to American Society of Industrial Designers.

(Meetings & Expositions on p. 236)

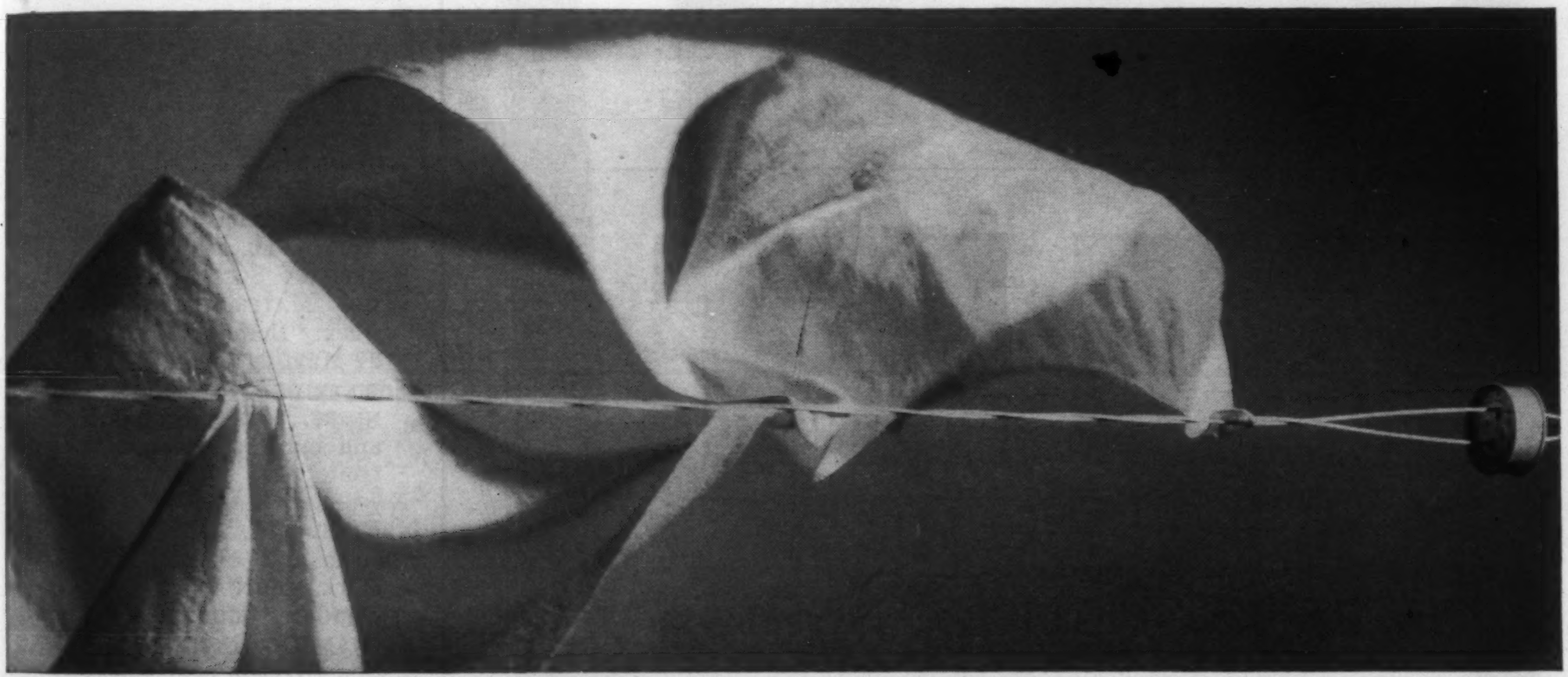
Coming in December

INDUSTRIAL TEXTILE FIBERS

by Theodore B. Merrill, Jr.



New twist for washday!



"Pin-O-Matic" Clothesline manufactured by **Dennan Mfg. Co.,** 1 Washington Ave., Providence, R. I.

BAKELITE Brand Elastomeric Vinyl plastic extruded on twisted twin strands of wire makes the new "Pin-O-Matic" clothesline gentle to both the wash and the housewife's hands. The line won't rust or flake. It is easily wiped clean, leaving the gleaming white surface smooth as new. No matter how often the strands are parted by the disk-shaped spreader, the jacket of BAKELITE Elastomeric Vinyl retains its resilience for a safe, secure grip.

This is only one example of how you can use BAKELITE Elastomeric Vinyl compounds in products that must resist water, heat, and cold. The flexibility of these compounds can be varied according to your needs, from semi-rigid to soft. Transparent, translucent, or opaque, these materials can be pigmented to a wide range of colors with a high-gloss or soft matte finish.

Learn how BAKELITE plastics and resins can help you market new products. Write Dept. LE-108.

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Vinyl Resins

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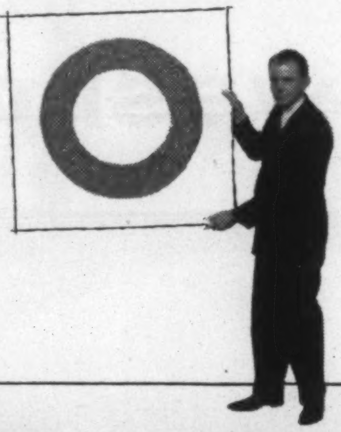
FROM **WICKS**



TO **WASHERS**

FELT

by FELTERS

DOES THE JOB RIGHT

Wicks that pull oil in — washers that keep dirt out — are two of many jobs done by Felters Felt, to keep equipment in good operating condition.

Hard enough to be ground and chiseled, soft enough to buff a jewel — or any texture in between — each shipment of Felters Felt is uniformly controlled to exactly meet your specs.

The "Felters Design Book" contains interesting information about several grades of Felt and their uses. We will be glad to send you a copy. Write today. THE FELTERS CO., 220 South St., Boston 11, Mass.

FELTERS S.A.E. F-1 FELT is a grade suitable for oil retention where the felt is not compressed, for feeding light oil, or where unusual strength and hardness are required. Often recommended for use in resisting wear and abrasion.

This is one of many grades of Felters Felt produced for specific applications.

FELTERS FELT

... by the roll ... by the yard
... or cut exactly as you want it

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Meetings and Expositions

Steel Founders' Society of America, annual technical and operating conference. Cleveland. Nov. 16-18, 1955.

Society for Experimental Stress Analysis, annual meeting. Chicago. Nov. 16-18, 1955.

Manufacturing Chemists' Assn., semiannual meeting. New York. Nov. 22, 1955.

American Institute of Chemical Engineers, annual meeting. Detroit. Nov. 27-30, 1955.

25th Exposition of Chemical Industries. Philadelphia. Dec. 5-9, 1955.

American Institute of Mining & Metallurgical Engineers' electric furnace steel conference. Pittsburgh. Dec. 7-9, 1955.

Nuclear Congress and Atomic Exposition. Cleveland. Dec. 10-16, 1955.

Society of Automotive Engineers, annual meeting. Detroit. Jan. 9-13, 1956.

Society of Plastics Engineers, annual conference. Cleveland. Jan. 18-20, 1956.

American Institute of Mining & Metallurgical Engineers, annual meeting. New York. Feb. 20-23, 1956.

American Society for Testing Materials, committee week. Buffalo, N. Y. Feb. 27-Mar. 2, 1956.

Society of Automotive Engineers, passenger car, body and materials meeting. Detroit. Mar. 6-8, 1956.

National Assn. of Corrosion Engineers, annual conference and exhibition. New York. Mar. 12-16, 1956.

American Society of Mechanical Engineers, Aviation Division conference. Los Angeles. Mar. 14-16, 1956.

American Society of Mechanical Engineers. spring meeting. Portland, Ore. Mar. 18-21, 1956.

Steel Founders' Society of America, annual meeting. Chicago. Mar. 18-20, 1956.

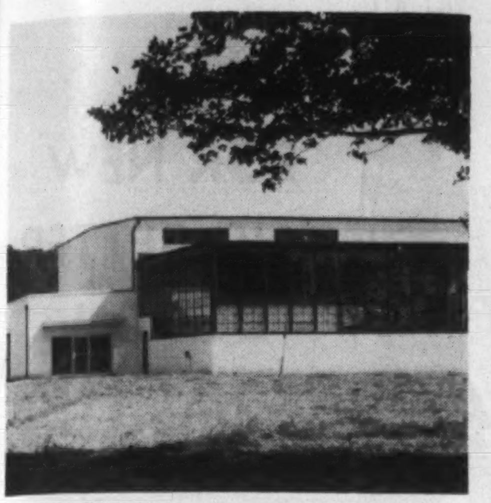
Society of Automotive Engineers, national production meeting and forum. Cleveland. Mar. 18-21, 1956.

American Society of Tool Engineers, industrial exposition. Chicago. Mar. 19-23, 1956.

American Society of Mechanical Engineers, Instruments and Regulators Division conference. Princeton, N. J. Mar. 26-27, 1956.

MATERIALS ENGINEERING NEWS

(Continued from p. 13)



Synthetic mica *is made in this expandable glass-walled plant in Clifton, N. J.*

mica will find greatest use in four reconstituted forms: as Supramica, a moldable and machinable form of glass bonded mica similar to Mycalex but with superior high temperature stability and strength; as one-component, self-bonded reconstituted sheet calendered and sintered; as block mica, a sintered machinable ceramic-like solid; and as phosphate bonded sheet for dielectric and sheet insulation applications. (For details see article "Three Forms of Synthetic Mica", MATERIALS & METHODS, Aug. 1954).

Research continues

Richard Humphrey, Chief of Synthetic Mica Corp.'s research and development program, told the visitors that the commercial production of synthetic mica, while a milestone, actually represented another step in the continuity of research carried out by Corning Glass Works, General Electric, the Army Signal Corps, Bureau of Mines, Office of Naval Research, Brush Beryllium Co. and others. Humphrey predicted that the larger equipment and greater production will accelerate application developments, which in turn will spur further advances in basic production techniques. He, too, emphasized that "Crystal size is a present limitation", but added, "Some of synthetic mica's properties not found in natural mica,

26,000 PARTS
POLISHED USING
THIS CHUCK

"IDEAS IN THE MAKING WITH CIBA PLASTICS"

Hear this!

REZOLIN
*TOOLPLASTIK
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MATERIALS ENGINEERING NEWS

such as higher temperature resistance and ability to bond to itself, may well provide us with means to circumvent crystal size limitation. We may be able to provide the electrical insulation user with materials he has only been able to wish for in the past without going to larger crystal size".

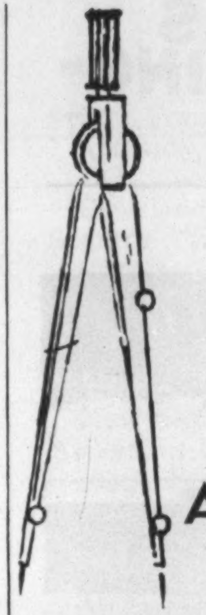
More reconstituted mica

There is another good reason for concentrating development on reconstituted mica other than the difficulty in producing large defect-free crystals. Even if these crystals were available, they are harder to split than the natural grades, and the tremendous expense of American hand labor for mica splitting would skyrocket the cost. Mycalex and Synthetic Mica Corp. believe that a thorough investigation and development program devoted to completely mechanized production of reconstituted synthetic mica materials will lead to a better way to produce high performance insulators at reasonable cost to the user. This does not mean that efforts to develop larger crystals are being ignored, however. Many compounds are still under investigation, and the roll of impurities in the melt is still only vaguely understood in its relationship to product quality and crystal size.

Experimental use

Properly qualified electronics researchers can get very limited quantities of splittable synthetic mica crystals up to 2-in. square for experimental use. None are sold commercially, however. Synthetic mica crystals have caught the interest of many electronics components designers and high temperature equipment manufacturers, due to such properties as: high light transmission, particularly in the ultra violet range; ease of degassification in vacuum; and temperature stability in dry atmospheres to 1475 F for extended time and over 1800 F for short time exposure.

(More News on p. 242)



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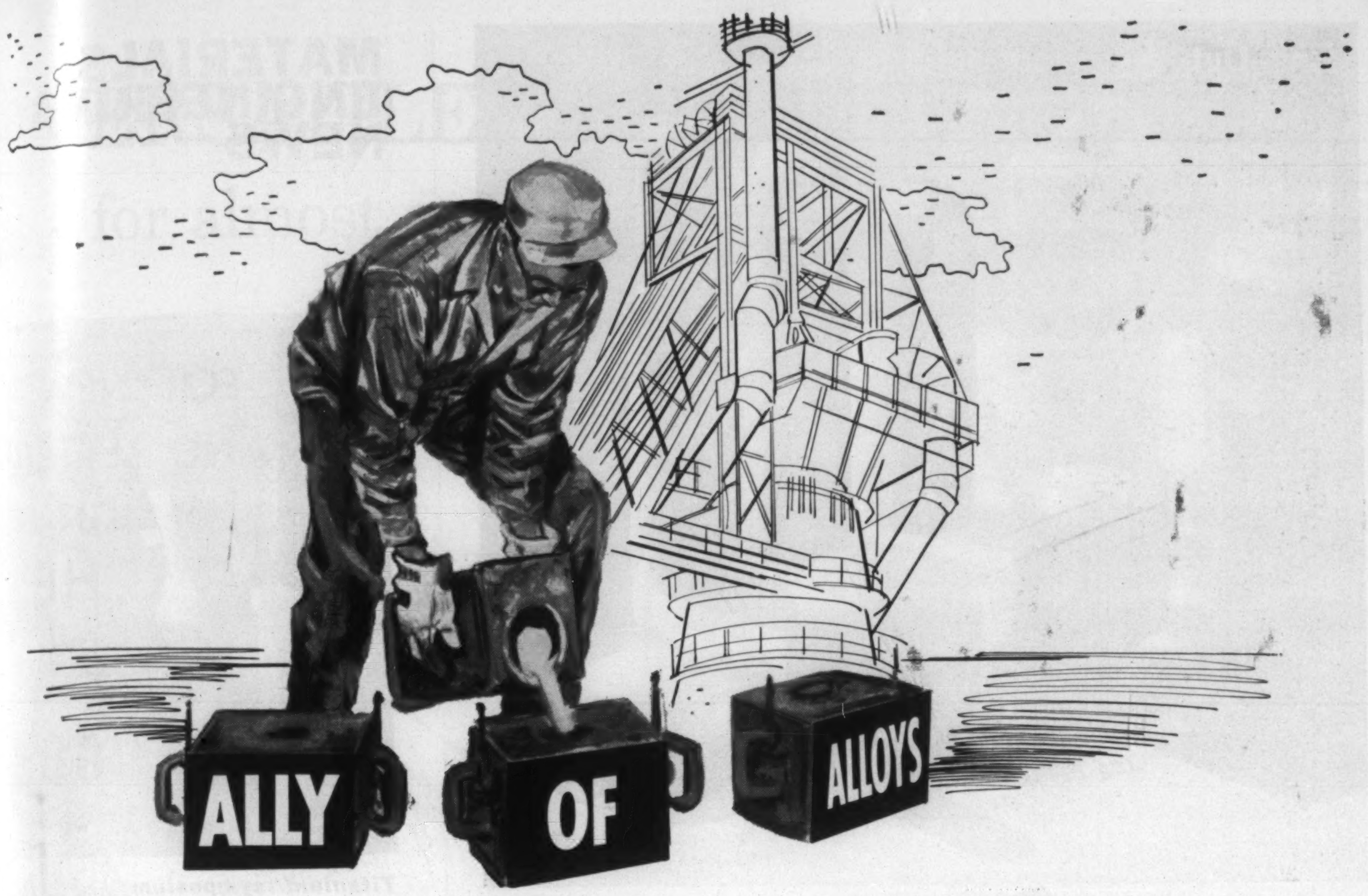

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Lithium, like metallurgy, has come a long way. Once a laboratory curiosity, lithium is now the "catalyst of industry." Once the art of separating metals from their ores, metallurgy now embraces a whole new industry devoted to the manufacture and treatment of the alloys of these metals. And now—still another new field within a field—Lithium Metallurgy.

Lithium Ingots are used in the degasification of copper. Lithium Cartridges are used in the refinement of high temperature copper, and in brass, bronze and nickel-silver castings. Even the salts of lithium (Carbonate and Chloride, specifically) hold great promise for heat treating.

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...trends ahead in industrial applications for lithium

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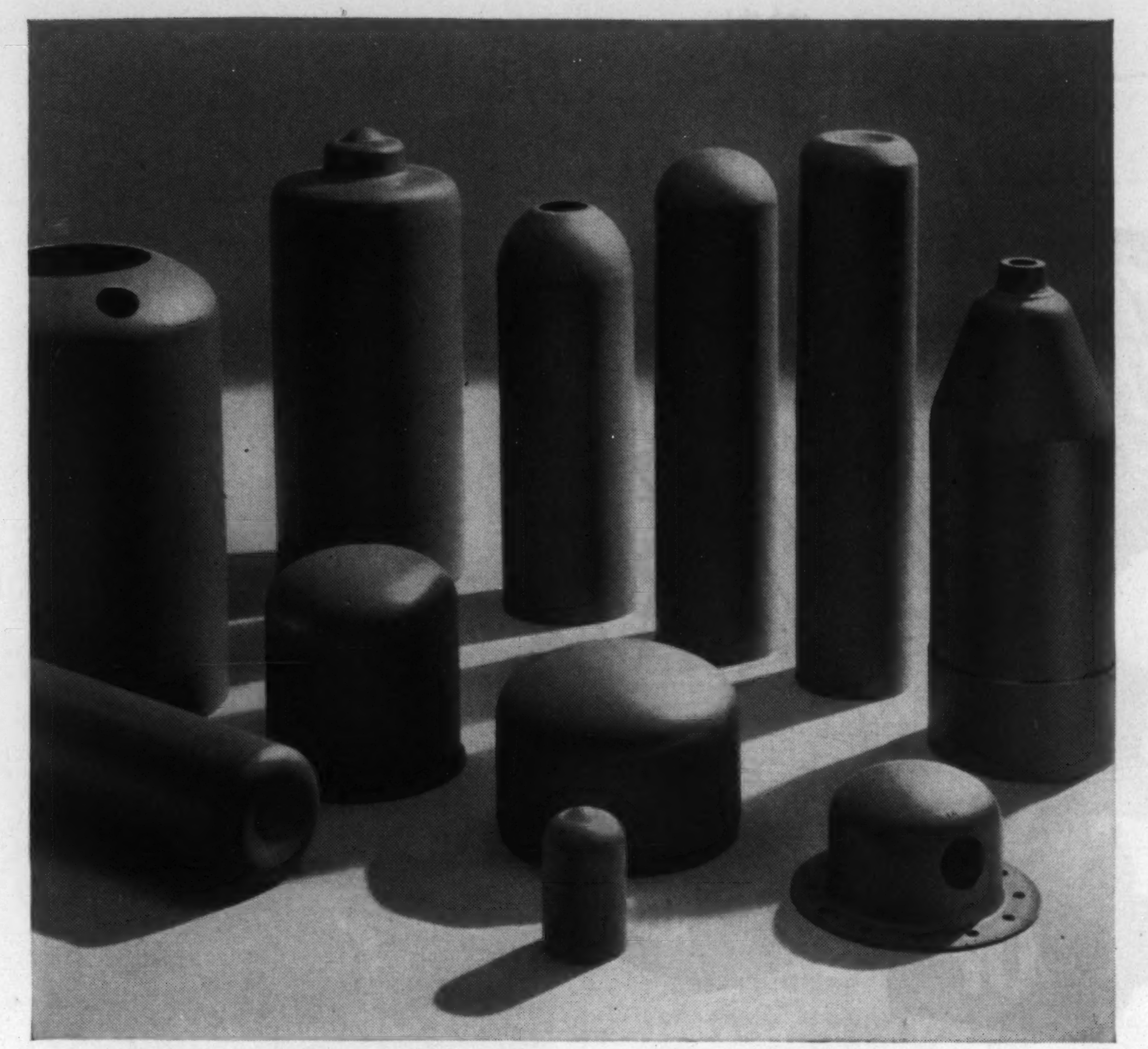

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MATERIALS ENGINEERING NEWS

Titanium symposium *heard Dr. William J. Kroll, inventor of the process for titanium extraction, talk on the outlook for titanium production.*

Titanium Symposium Hears Experts

Soon after Defense Mobilizer Arthur Fleming put the brakes on further expansion of raw titanium sponge production, a previously scheduled one week course in titanium metallurgy took place in New York City. Jointly sponsored by the ASM and New York University's Department of Metallurgy, the course was strictly limited to about 160 technically competent engineers and executives in industry and government from the United States, England and Canada. The course, consisting of lectures by 22 leading scientists and engineers, shed considerable light on the state of the titanium art.

The governmental decision to hold back on further titanium production occurred largely as a result of the imbalance of supply and current projections of use. This year, it is estimated that production will hit 7700 tons, while consumption will be less than half this amount. By the end of next year production facilities now building

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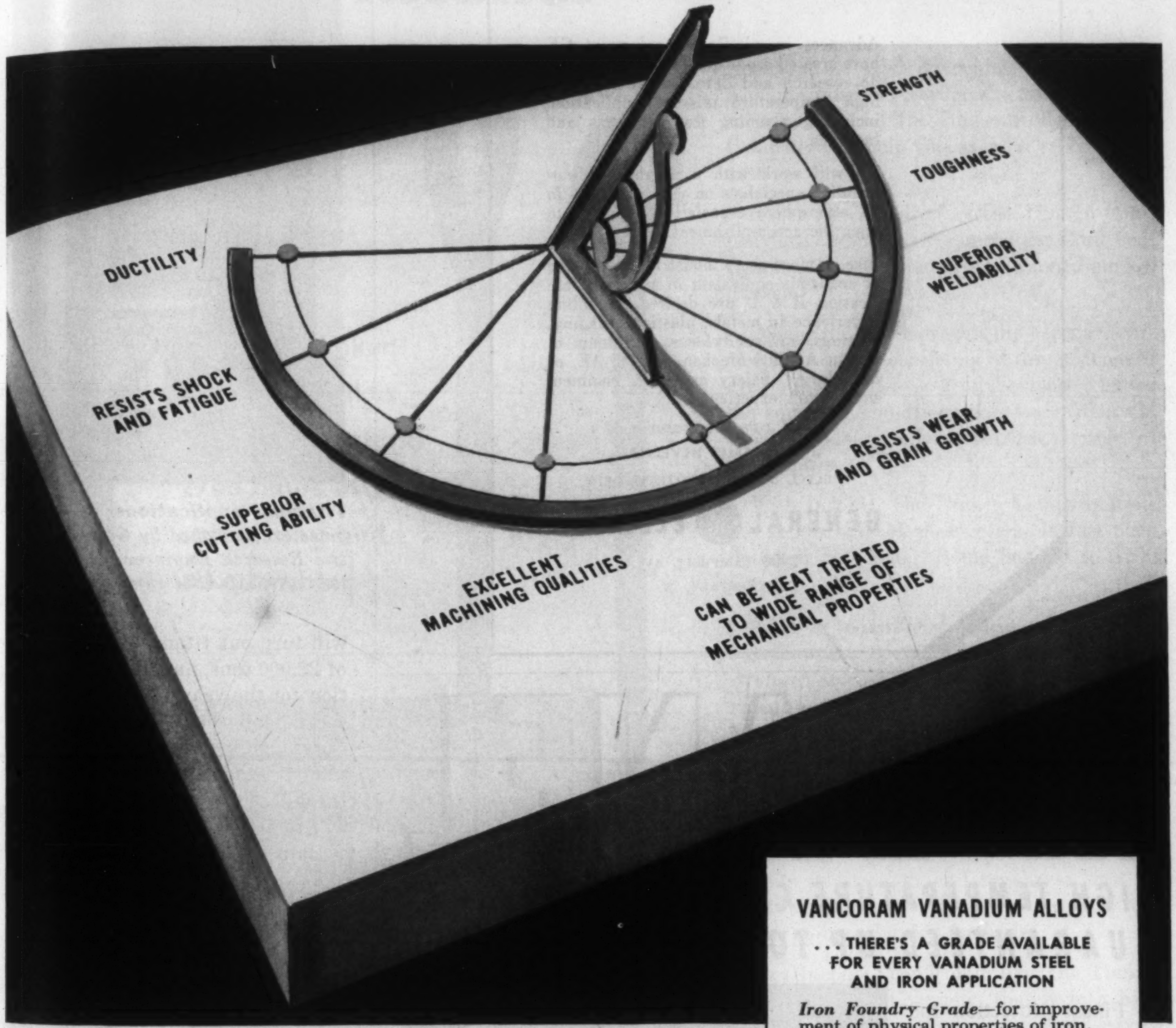
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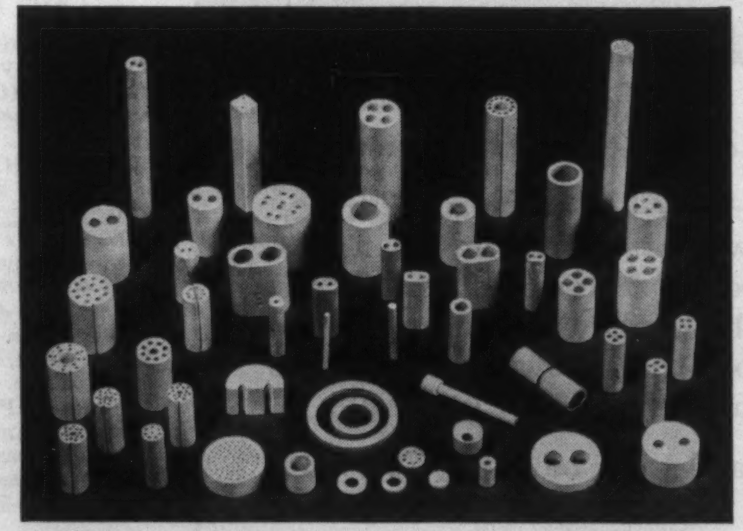

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MATERIALS ENGINEERING NEWS

***Titanium applications** in jet engines are described by General Electric Research Engineer M. E. Cieslicki at NYU-ASM symposium.*

will turn out titanium at the rate of 22,000 tons, and annual production for the year 1956 will total in the neighborhood of 15,000 tons. Consumption for the year, barring a surprising technological breakthrough or national emergency, will total a mere 8000 tons.

Data supplied by the lecturers at NYU showed why the titanium stockpile is not sold out. On the other hand, the lecturers made no bones about the fact that titanium has enough superiority over convential materials to win a lasting, and large volume position among structural materials.

Why titanium?

Speaking from his experience with the Navy Department Bureau of Aeronautics, introductory lecturer N. E. Promisel summarized the factors that make titanium so useful as a structural metal, yet so difficult to use today. He said, "Although interest in titanium was in part generated by (its) corrosion resistance, lack of magnetic properties, high electrical resistivity, low thermal expansion, and so on, the major excitement and enthusiastic anticipation for the use of titanium

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How long do *your* quenching fixtures last? And how much do they have to take? Perhaps the experience of The Timken Roller Bearing Company can help you save on replacement costs.

Roller bearing parts at The Timken Company are carburized in natural gas. This heat treatment is followed by an immediate oil quench.

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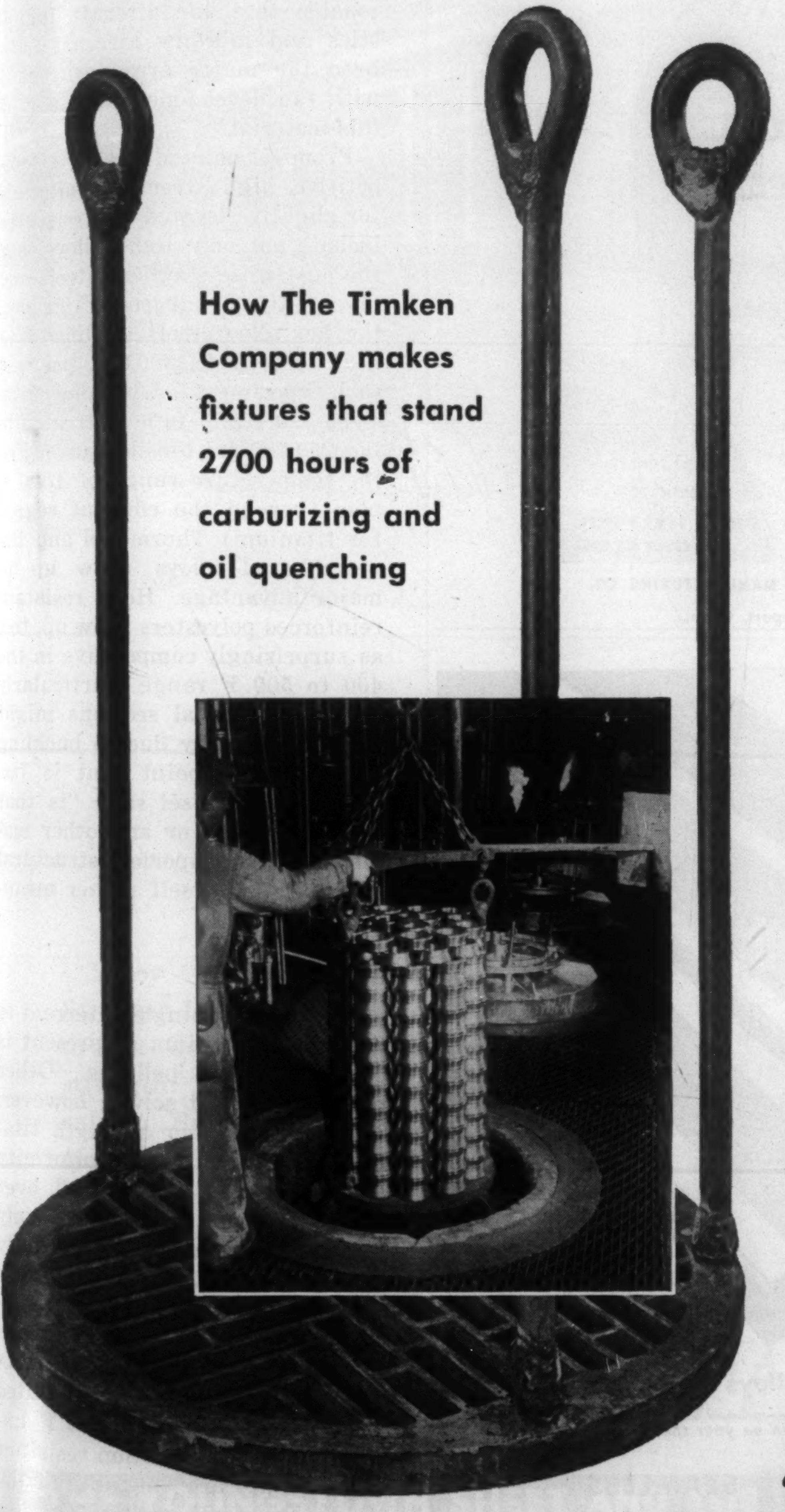
How The Timken Company makes fixtures that stand 2700 hours of carburizing and oil quenching

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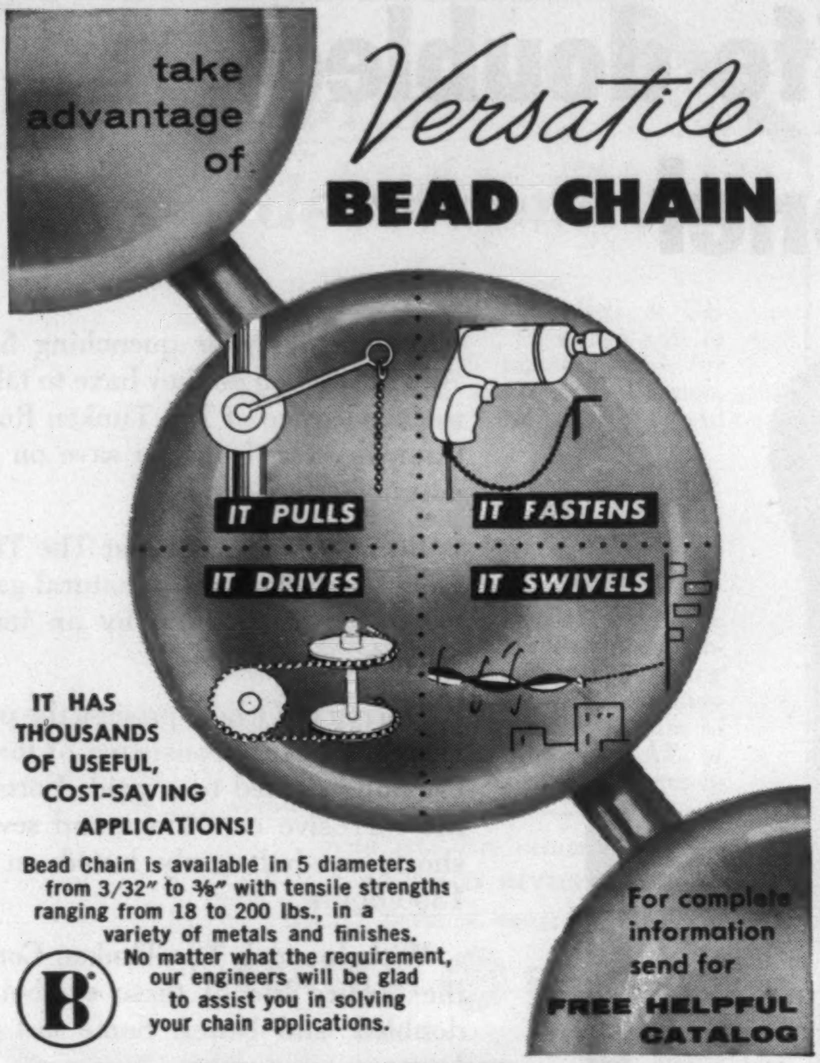

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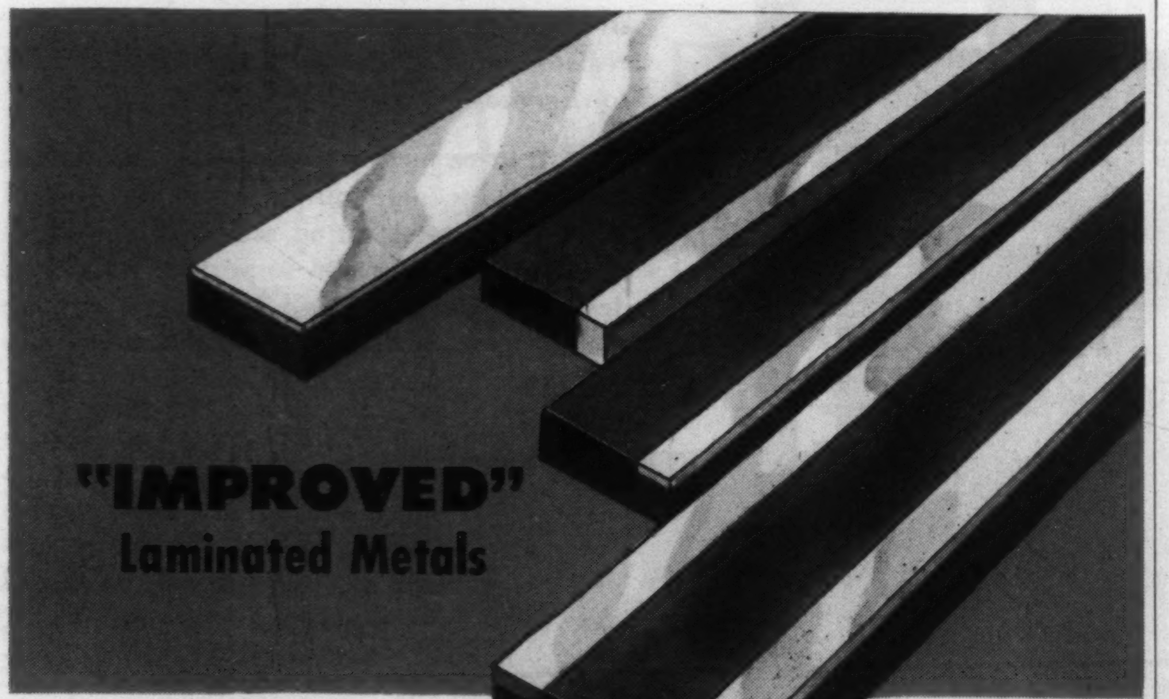

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has resulted from its high physical properties, or better stated, strength-weight ratios. It is reasonable that the aircraft industries and military aircraft have been the major areas concerned with the development and use of this material."

Promisel pointed out that competitive high strength materials for slightly elevated temperatures include not only light alloys, but the austenitic stainless steels and precipitation hardening grades, the low alloy steels modified and heat treated to 300,000 psi and such experimental developments as Type 420 stainless heat treated to the 250,000 psi tensile range. For the temperature range of 1000 F plus (beyond the efficient region for titanium) Thermenol and the nickel-based alloys show up to major advantage. Heat resistant reinforced polyesters show up, too, as surprisingly competitive in the 400 to 500 F range, particularly where thin metal sections might be unsatisfactory due to buckling factors. "The point that is important," Promisel said, "is that to say titanium or any other material is the superior structural material is in itself rather meaningless."

Some problems

The greatest single deterrent to the use of titanium at present is cost, Promisel believes. Other problems are not solved, however. The use of higher strength titanium alloys will start uniformity and reliability troubles all over again—troubles which have only recently been reduced in presently available alloys. Alloys with higher modulus and lower density are required for applications in which critical buckling and shear problems exist. Titanium will be limited to applications under 1000 F unless totally new oxidation resistant alloys that are metallurgically stable are forthcoming. Greater use of scrap titanium is a desperate need at present and will continue to be even after costs are re-

7
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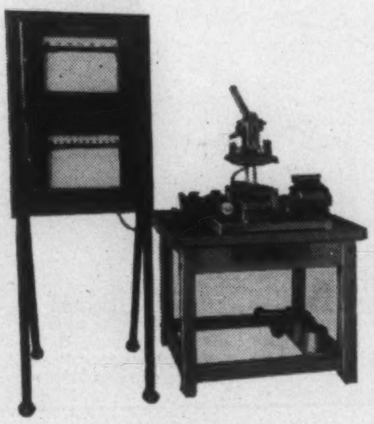
A well known manufacturer of airplanes

is at present establishing a laboratory containing several models of Scott Testers* for the purpose of evaluating the various elastomers offered. (One of these is illustrated here: the Scott NBS Mooney Viscometer).



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duced considerably.

In general, Promisel felt that the ultimate important position of titanium is no longer "Will it?" but "When will it?". "It is becoming increasingly evident that design and performance of military weapons of the future will be limited by technical deficiencies in materials. Titanium is helping to fill this gap in supermaterials."

Titanium in Europe

Professor Nielsen of NYU's Metallurgy Department (see Men of Materials, p. 9), the man behind the conception of the titanium course, had just returned from a survey trip to Europe, during which he had picked up a current picture of the titanium art abroad. He reported that interest was high, but that the titanium industry was scarcely past the research stage in any country except England. He estimated that English research efforts were about 20% of those of the U.S., but were largely privately financed. England's production of 1500 tons per year stems largely from ICI's plant, which Nielsen characterized as "outshining anything I've seen in this country".

In response to questions about industry-wide standards for titanium alloys, two of the lecturers, Herres of Titanium Metals Corp. and Finlay of Rem-Cru Titanium, agreed that there had been no effort to standardize to date for fear of delaying the introduction of new and better materials. The nearest to a standard, they said, is the alloy 6Al-4V which is now available from three of the four producers, and the fourth is producing it, though not for sale. Promisel added that the Government had a program on sheet evaluation which was intended to speed development of new sheet alloys. The Battelle coordination program on titanium research was reportedly starting to show results.

Alloy development trends

The most important direction of alloy development as revealed by

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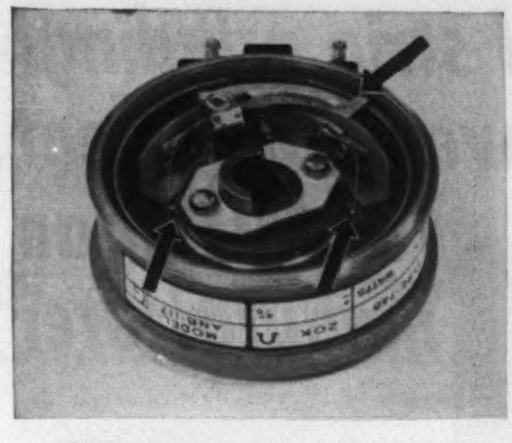

Arrows point to Paliney #7 contacts used in this Fairchild Type 746 Precision Potentiometer.

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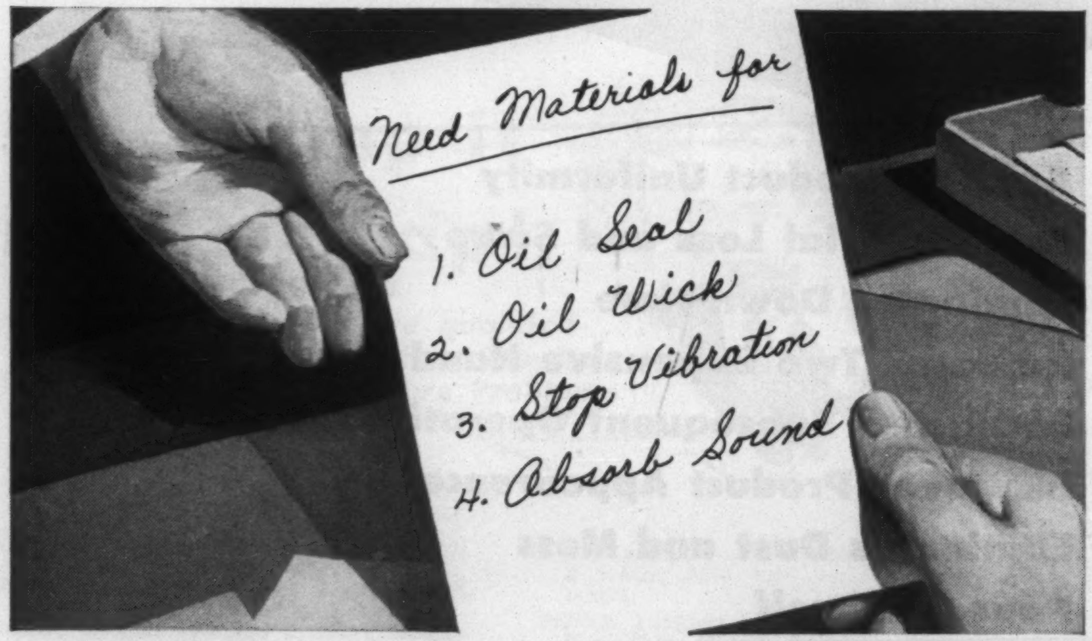

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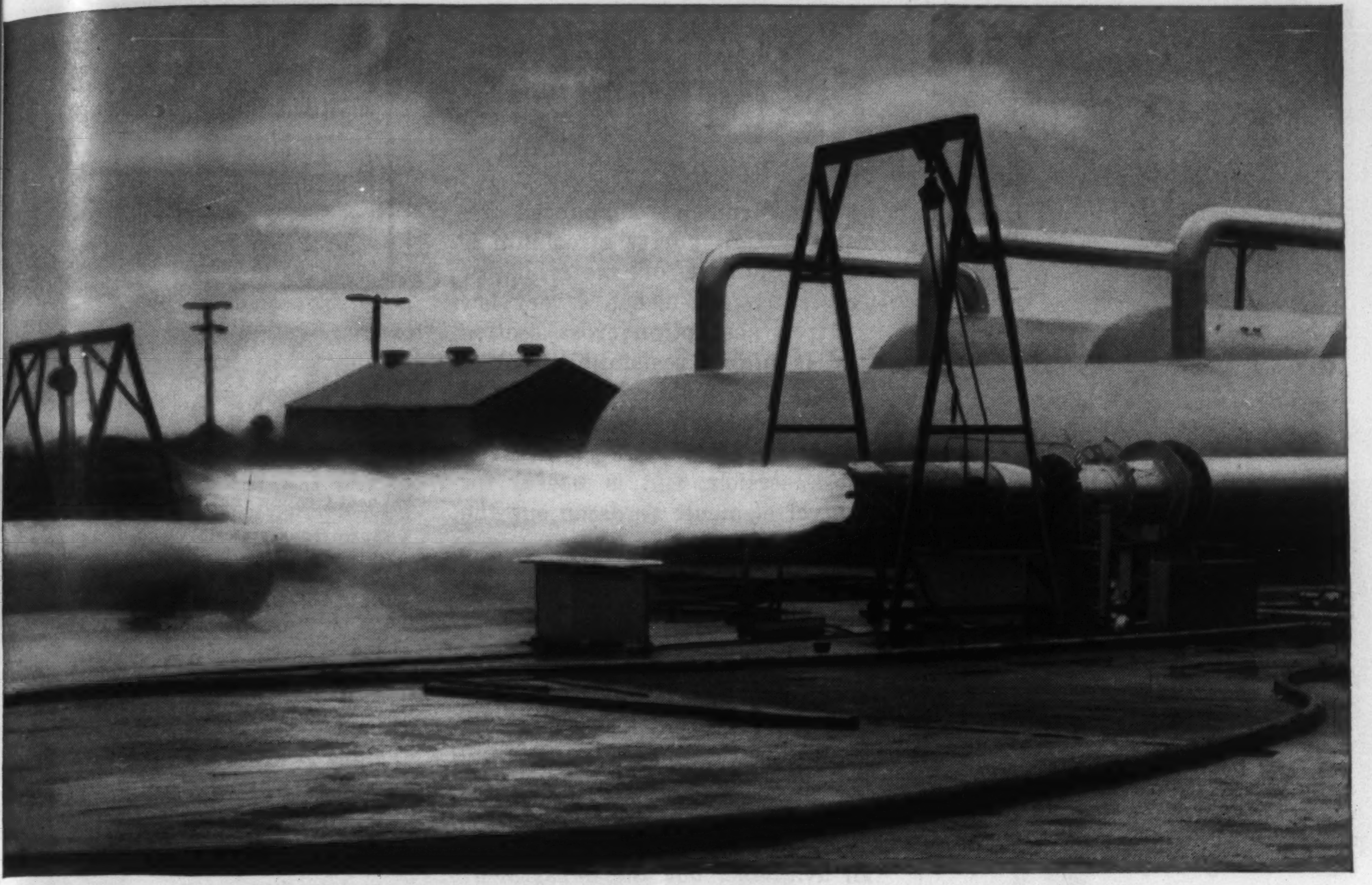
MATERIALS ENGINEERING NEWS

several course lecturers is the abandonment of using interstitials on a design basis in alloys. Interstitials are too difficult to handle on a production basis, and use of alloying elements such as aluminum, vanadium and molybdenum should be used to develop improved properties and stability. Avoidance of interstitials indicates the use of the softest sponge possible. The development of the molybdenum and manganese alloys typifies the trend. Molybdenum apparently imparts the maximum creep stability and best high temperature properties to titanium alloys, and McPherson of Armour Institute predicted that commercial alloys containing molybdenum would be available soon. At present, there are twelve commercial alloys, and future alloys will probably be based on aluminum and tin for alpha; manganese, molybdenum and vanadium for beta. Iron and chromium alloys will probably be dropped, according to McPherson. A qualified guess for the future by McPherson is that alpha-beta alloys will continue to be the most generally useful, although present alloys will be replaced by improved versions; all alpha will be developed to combine weldability and high strength, but will pose forming problems; all beta alloys will appear which will combine advantages of all alpha with greater formability; and precipitation hardenable alloys based on compound formation may make their appearance. To emphasize confidence in his own predictions, McPherson held up a crystal ball for the audience to see.

AEC Won't Supply Pure Zirconium for Civil Projects

Privately financed nuclear power projects will not be able to get hafnium-free zirconium or high purity hafnium from the AEC,



Ramjet tailpipes withstand severe abuse. (*Photo courtesy Marquardt Aircraft Company*)

MULTIMET Alloy Controls the Blast of Ramjet Engines

Tailpipes used to direct the searing blast of power in today's ramjet engines must withstand temperatures in excess of 2000 deg. F, plus severe vibration. High-speed ramjets operate in the neighborhood of 1500 mph. At these high speeds, vibration is almost as serious a threat to tailpipe life as heat. Because of its strength at high temperatures, MULTIMET alloy has given good service in tailpipes that vibrate as much as three inches.

Ramjet tailpipes are made of MULTIMET alloy sheet that is only 0.051 to 0.078 in. thick. The combined high-temperature strength and oxidation resistance of MULTIMET alloy permits the use of lightweight tailpipes with good heat-transfer properties.

MULTIMET alloy is one of many HAYNES alloys capable of extending the life of parts used at high temperatures. For literature describing the properties of HAYNES high-temperature alloys, get in touch with the nearest Haynes Stellite Company Office.

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ALLOYS

HAYNES STELLITE COMPANY
A Division of Union Carbide and Carbon Corporation
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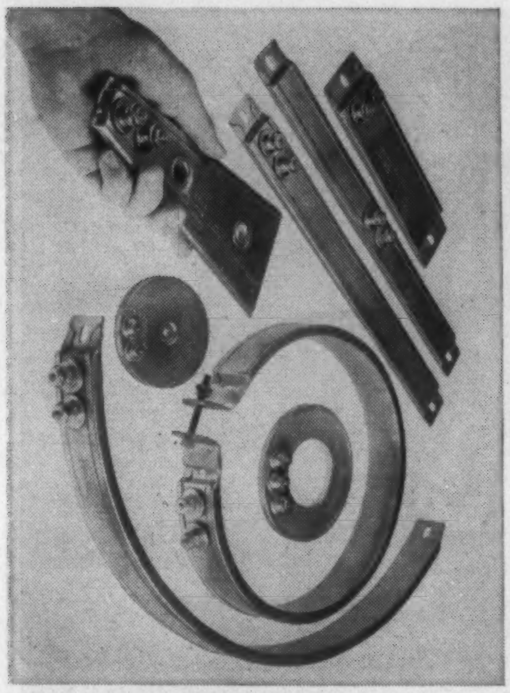


Newmanufacturingprocess improves performance of CHROMALOX Electric Strip Heaters

An improved manufacturing process, combined with a newly developed refractory material, offers you the finest performance in strip heaters. Rugged and long lasting, they are industry's workhorse among heating elements.

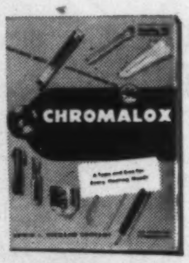
So when you use the improved line of Chromalox Electric Strip Heaters, you're assured of even better performance in the heating of platens, dies, kettles, tanks, ovens, air ducts and other applications that require dependable, accurately controlled heat . . . where and when heat is needed.

Let the Chromalox Sales-Engineering staff solve your heating problems—electrically.

Write for your copy of Catalog 50

This data-packed catalog covers the design, uses and prices of the complete line of Chromalox Electric heaters, elements, thermostats, contactors and switches.

To get short factual material on many additional applications of electric heat, send for Booklet F1550 "101 Ways to Apply Electric Heat."



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MATERIALS ENGINEERING NEWS

the government announced recently. High purity zirconium is one of the best core materials for reactors, since it has a very low neutron absorption cross section and is highly resistant to corrosion by a number of chemical compounds. Hafnium, on the other hand, has a very high neutron cross section, and is useful for control elements to damp out the nuclear reaction.

~~Zirconi~~um ore always contains some hafnium, and separation of hafnium and zirconium involves complex processing due to the chemical similarity of the metals. To date, the AEC has strictly controlled hafnium-free zirconium, and has required that all of it produced be sold to the government. Not only is the AEC buying all available, but the department has recently solicited proposals for delivery of 2,000,000 lb of high purity zirconium over a five year period, or 1,200,000 lb over a three year period. The proposals also cover delivery of as much hafnium metal as can be produced from the processed zirconium. At present, AEC has a contract with Carborundum Metals Inc., calling for delivery of 200,000 lb of zirconium and 4000 lb of hafnium per year. The new procurement will be in addition to this amount. Any hafnium-free zirconium left after government requirements are fulfilled will be available to industry, and the government has urged its prospective suppliers to plan for the private market that is expected to develop.

NEMA Topics: Copper, Insulation

Materials for the electrical industry were in the spotlight at the NEMA Wire and Cable Section annual meeting held recently. The copper supply situation was in particular focus, as the meeting was held at the peak of the copper shortage. William A. Meissner, deputy director of the Copper Div.

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Radiation Pyrometer

Tells spot temperatures instantly in heat-treating furnaces, kilns forgings and fire boxes. No thermocouples, lead wires or accessories needed! Temperature indicated on direct-reading dial at a press of the button. Any operator can use it. Two double-ranges from 1000° F. to 3400° F. Write for FREE Catalog No. 100.

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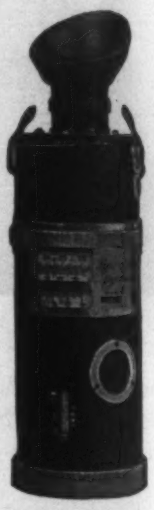
Determines temperatures of minute spots, fast-moving objects and smallest streams—at a glance! No correction charts or accessories needed. Easy to use—weighs only 3 lbs. Special types available to show true spout and pouring temps of molten ferrous metal measured in open. Five stock ranges from 1400° F. to 7700° F. Write for FREE Catalog No. 85.



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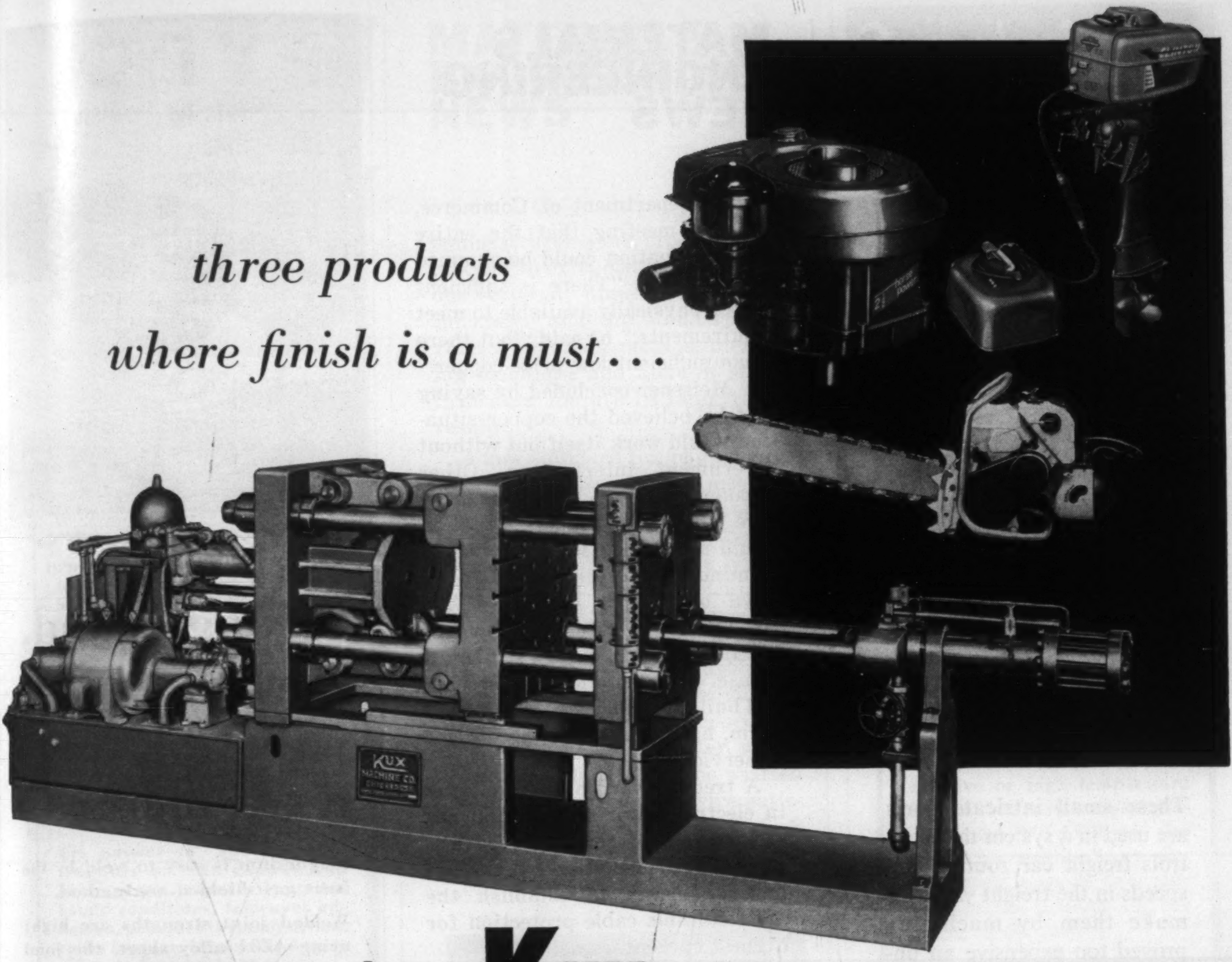

three products
where finish is a must . . .

so **CLINTON** chose **KUX**
DIE CASTING MACHINES
to get hardware finish quality castings

Every sales manager has told his production department at one time or another, "The product's fine, but you've got to dress it up."

At which time the production man starts talking about increased costs.

But many manufacturers have found they can "dress up" their products, and at the same time, *lower* manufacturing costs.

The Clinton Machine Company, Clinton, Michigan, did just that. "We use Kux Die Casting Machines in the manufacture of approximately 60% of the component parts of our Clinton engines, chain-saws and outboards.

"We chose Kux because our standards require machines that give us a dense, hardware quality finish with castings to close tolerances. The efficiency and low maintenance costs of Kux Machines have cut our production costs sharply, too," says R. E. Porter of Clinton Machine.

KUX produces a full range of modern die casting machines that require only the touch of an electric button to put them automatically through a complete casting cycle at high production speeds. Kux engineers will be glad to show you how die casting machines can serve you, or write for an illustrated catalog.

MODEL HP 37 ILLUSTRATED
Hydraulically operated die casting machine for production of aluminum casting weighing up to 10 pounds.

KUX MACHINE CO. 6725 NORTH RIDGE AVENUE • CHICAGO 26, ILLINOIS

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The tough jobs are easy

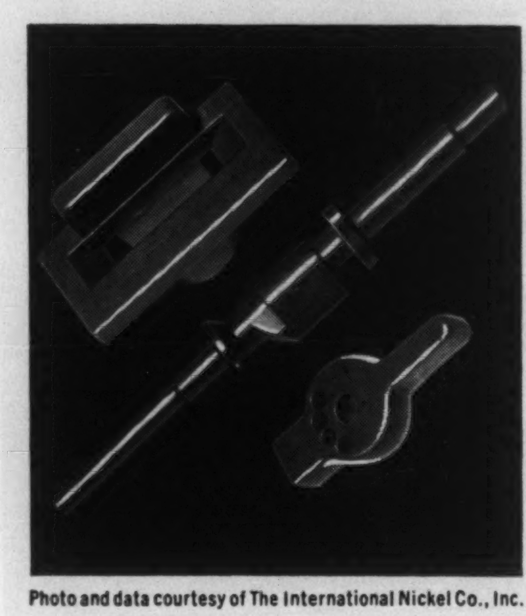


Photo and data courtesy of The International Nickel Co., Inc.

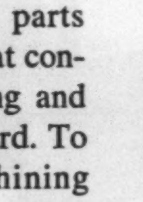
with INVESTMENT CASTING

These small intricate parts are used in a system that controls freight car routing and speeds in the freight yard. To make them by machining proved too expensive an undertaking in both time and materials.

That's when Investment casting was put to the test. The results were very successful. The cam shaft for example was cast to tolerances of plus or minus .005" per linear inch. This is another example of the time and cost savings possible with this modern precision casting technique.

WRITE TODAY for the INVESTMENT CASTING STORY

This free 12-page booklet —"MODERN PRECISION INVESTMENT CASTING"—contains detailed data on the Investment casting process.



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MATERIALS ENGINEERING NEWS

of the Department of Commerce, told the meeting that the entire copper situation could be summed up by prices. "There is sufficient copper physically available to meet requirements," he said, "but there is not sufficient low price copper." Mr. Meissner concluded by saying that he believed the copper situation would work itself out without government interference. Other speakers on the program made sure that the copper situation would not work itself out without aluminum interference. Ray G. Boyd of Kaiser Aluminum and Dr. George Perkins of Reynolds Metals Co. both plugged for greater use of aluminum magnet wire and building lead wire, which, they claim, has been thoroughly proved in service.

A trend toward higher voltages in electric power distribution has created a need for improved materials for insulation. Tests are now underway to establish the most suitable cable protection for highest current capacity.

For insulation of cables in the 2 to 35 KV range, rubber insulation is now in greater use, according to G. J. Crowdes of Simplex Wire and Cable. He presented comparative data between the newer butyl rubber insulating materials and natural and oil based insulation. Comparative tests and field data experience show that the butyl insulation has greater resistance to heating, aging and deterioration from moisture, ozone and corona. Generally, butyl insulated cables can operate at higher normal temperatures as well as higher emergency and short-circuit loads than cables insulated with materials that have a higher dielectric constant and power factor, as well as lower resistance.

A standard for extruded wire insulation will be given a six month trial, according to Crowdes. The standard, which sets dimensional tolerances, will be adopted if it results in less need for inspection and provides the user and

Welded pressurized housing for airborne electronic equipment

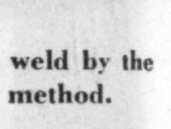
Strong, sound, lightweight welded assemblies

Magnesium is easy to weld by the inert gas shielded arc method.

Welded joint strengths are high; using AZ31 alloy sheet, the joint strengths average 86% of the parent metal with all weld bead ground off smooth. If a bead is left, strengths can equal or exceed the parent metal strength.

Magnesium welds are not subject to microporosity so common with many metals. The average magnesium weld is sound and pressure-tight. Where the designer must enclose his electronic equipment in a pressurized heat exchanger, magnesium is his most satisfactory material . . . and the added bonus is light weight.

B&P engineers will help you redesign in magnesium. B&P offers the magnesium industry's most complete facilities for fabrication and assembly. Your inquiry will bring answers to problems of magnesium welding: this 12-page booklet.



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The answer to "spotting out" troubles on thin copper and brass plate, especially under humid conditions. Improves adhesion, provides leveling action, saves lacquer. Eliminates fingerprints before assembly.

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Luster-On products are manufactured on the West Coast by Crown Chemical and Engineering Company of Los Angeles, Calif., and in the Dominion of Canada by Alloycraft Limited of Montreal, Quebec.

You'll also be interested in our Safety Division's line of industrial skin cleaners and protectors . . . protect your workers and your products. Literature available.

L-18

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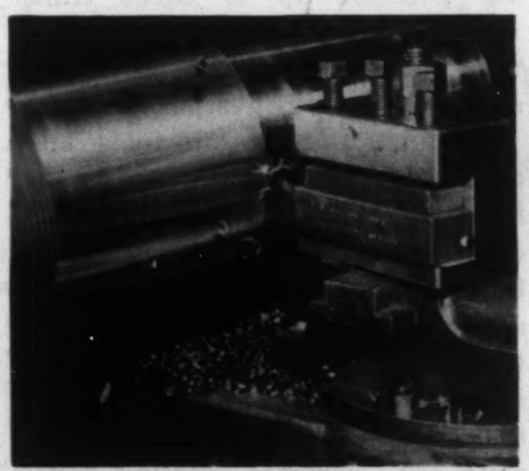
manufacturer more product information. In extruded insulation, the one critical dimension is wall thickness, and the standard provides a sampling method, measuring technique and table of statistical data for use in interpreting results.

A new standard for magnet wire was also discussed at the meeting. R. L. Reading of Belden Manufacturing urged that serious thought be given to switching the NEMA standards for magnet wire from individual material standards to an over-all performance standard, since too many suitable insulating materials were now available to warrant a separate standard for each material. As a starter, a performance standard will be written for film coated magnet wire satisfactory for operation at class B temperatures.



***Slicing off** a ¼-in. cut at 1500 SFPM at a 0.01 in. feed, ceramic tool makes SAE 4140 chips fly without heating work piece or tool holder.*

Ceramic Tools Available for Test

Ceramic metal-cutting tools, stemming from The Army Ordnance research conducted by Rodman Laboratory at Watertown Arsenal are now available to industry in limited quantities for research and machining studies. The Norton Company, which was associated with the Watertown re-

Graph-i-tite

SOLVES CORROSION AND HIGH TEMPERATURE PROBLEMS

Graph-i-tite . . .

is a carbon-impregnated graphite material of construction, which can be formed into cylinders, tubes, nozzles, crucibles, molds, and special shapes. It is used to contain fluid flow in reactors, for piping, nozzles and processing equipment used in production of chlorine, chlorinated metals, molten salts, and in other corrosive or high temperature chemical and metallurgical processes. GRAPH-I-TITE may also be used for crucibles for transistor crystal growth, as rocket nozzle inserts, as well as a power reactor moderator.

Graph-i-tite . . .

possesses exceptional heat transfer characteristics, and is unaffected by most corrosives. It is impermeable, immune to thermal shock, non-wettable, non-contaminating, will not absorb radiation, and withstands operating temperatures up to 5700° F.

In addition, custom formulated graphite (impregnated or untreated) can be supplied with specified purity, density or other properties for special applications. Extrusion, molding and machining facilities are available for limited or high production work.

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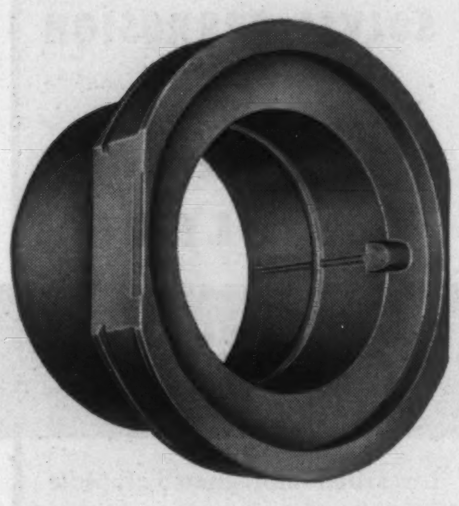
do you have internal problems?



Precision Investment Casting can solve many difficult internal machining problems such as putting in 3/64" ribs shown in the above part. This piece weighs ¾ of a pound, measures 2¾ inches in overall diameter and is cast in 410 stainless steel. Inside diameter is held to plus or minus .005".

Check this process today as a means of reducing some of your costs on expensive and difficult parts. We would be pleased to have you submit your prints without obligation for consideration or quotation.

GRAY-SYRACUSE INC. . . . . . .

W. Seneca St., Manlius, N. Y.
Small precision castings of ferrous and non-ferrous alloys.

Gray-Syracuse, Inc.
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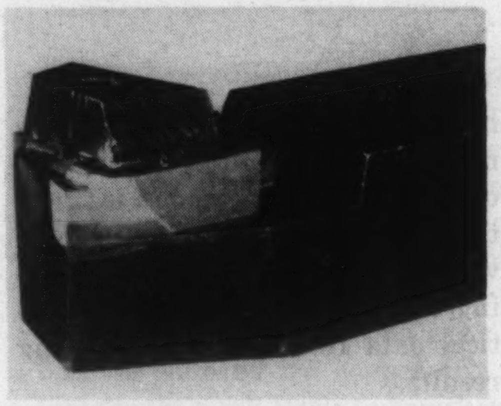
MATERIALS ENGINEERING NEWS



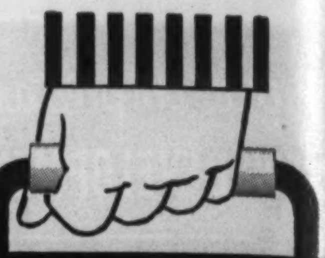
***Ceramic tool** in special holder.*

search is producing the tools under the trade name Alundum. The company warns that the tools are strictly in the development stage, and that special precautions and equipment are necessary with use.

The ceramic cutting tools, made of a sintered aluminum oxide, seem to have a definite future for two reasons: 1) the material is non-strategic, inexpensive and common, 2) the initial performance test results show that with proper rigid toolholders and high speed equipment, cutting speeds are possible up to three times faster than most cutting tools will take (For details of initial test results see News Digest, July 1955).

In using the ceramic tools, special tool geometry and equipment is necessary because the aluminum oxide tool piece has much lower thermal shock resistance and tensile strength at room temperature than metal or carbide tools. As more rugged and more powerful tools become available, the superiority of ceramic tooling over standard tooling is expected to increase. The tools produce an excellent surface finish at high speeds, and require no coolant. Both workpiece and cutting tool remain cool to the touch when the tool is operated at the proper angle and chip breaker adjustment. On cast iron with sand holes, which normally is difficult to machine, the ceramic tools cut through without chatter or tool fracture. The tool resists cratering and dulls more slowly even at high speed by a factor of two over other tooling materials.

(More News on p. 260)



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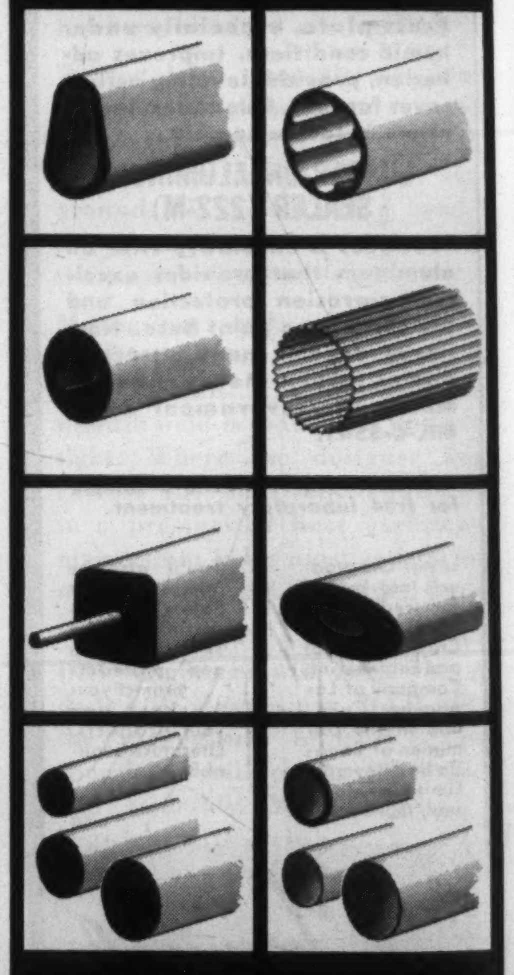

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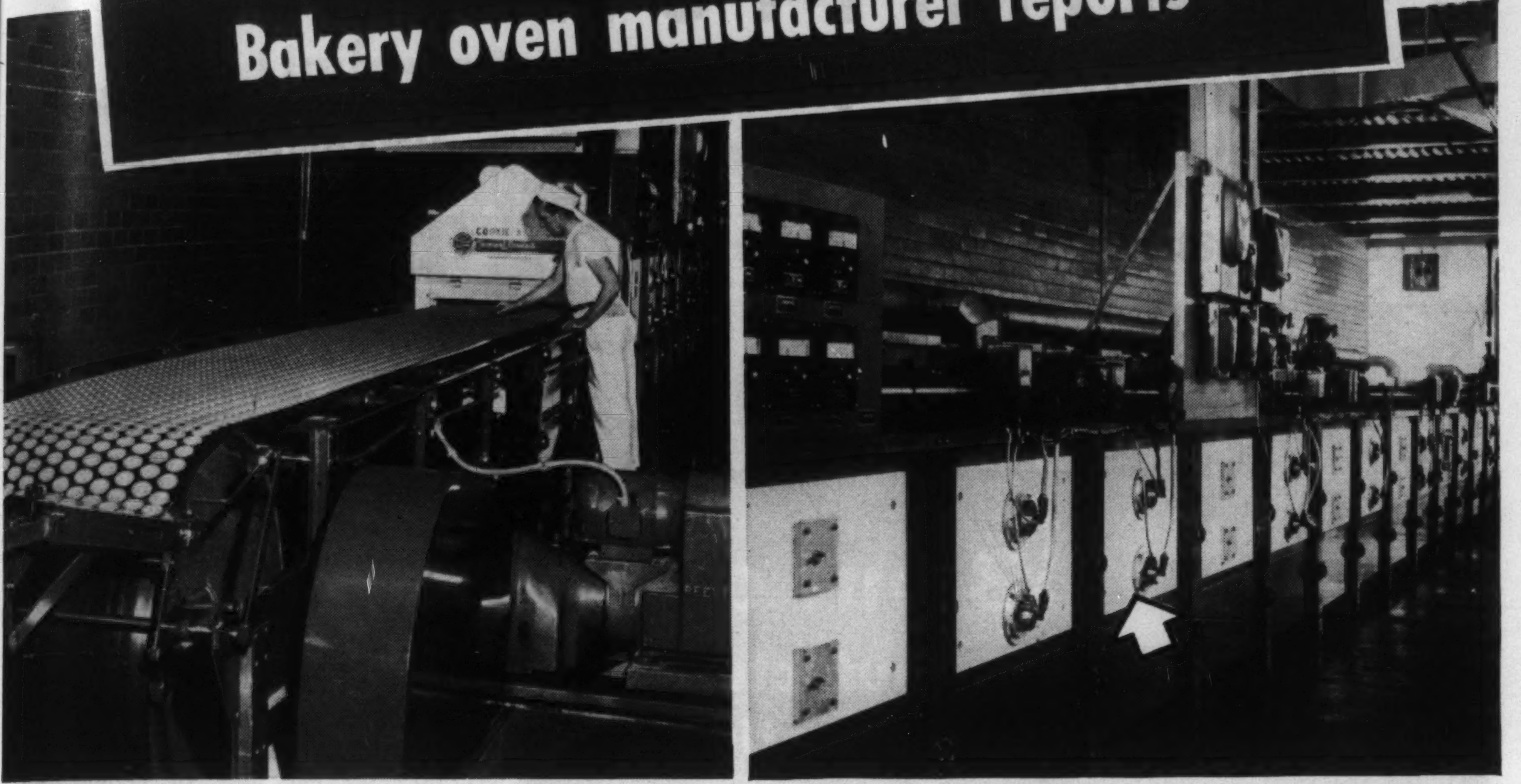
Bakery oven manufacturer reports—



Thomas L. Green & Company's new 100-foot band oven, built and insulated with Johns-Manville Marinite (shown by arrow above). Photos by courtesy of "Rippin' Good Cookies," Ripon, Wisconsin.

"Faster heating ... better performance"

for ovens built of J-M Marinite

the non-corroding, structural insulating material

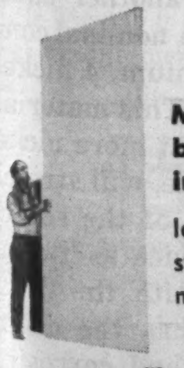
This leading bakery oven manufacturer, who designs for lasting customer satisfaction, obtains several major advantages by using Johns-Manville Marinite*, the structural insulating material:

(1) Marinite-built ovens heat up faster than ovens with all-metal construction. (2) Marinite provides better heat control and more flexibility—temperatures may be quickly raised or lowered for baking different products. (3) Marinite saves space and weight, yet affords the same thermal insulating effectiveness as blanket-type insulation supported by heavy metal construction.

Equipment users find other advantages . . . In addition to superior performance, operators of ovens, driers and other high temperature equipment obtain almost unlimited service life from Marinite. This asbestos material combines structural strength and durability with efficient thermal insulation. It requires virtually no maintenance. It does not rot or corrode. It will not disintegrate in water. It requires no finish or protective facing for normal service.

To learn how Marinite can improve your equipment, write Johns-Manville, Box 60, New York 16, N.Y. In Canada, 199 Bay St., Toronto 1, Ontario.

*Marinite is a registered Johns-Manville trade mark.



MARINITE builds and insulates in one operation

large, structurally strong sheets afford maximum heat control

MARINITE is easily worked

may be cut, drilled, shaped and fitted with ordinary woodworking tools

MARINITE speeds construction

can be erected without costly equipment—requires minimum angle-iron framing

Johns-Manville *FIRST IN* INSULATION

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the Nickeloid Way

3 out of 5
manufacturing
steps entirely
eliminated
more than a metal
it's a method!

Even before they arrive at your plant, Nickeloid PRE-Plated Metals are 60% through your production process. No cleaning, plating or polishing . . . that's been done for you—expertly, uniformly, accurately. You just fabricate; then assemble. By-pass 3 out of 5 basic production steps. Reduce costs up to 20%; save time and lower investment in inventory and equipment.

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A variety of finishes and patterns

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In handy slide-chart form, gives specifications, finishes and typical uses of Nickeloid Metals. 8 metal samples. Request yours on your company letterhead.

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MATERIALS ENGINEERING NEWS

Low-Nickel Stainless Data Released

The continuing shortage of nickel has prompted Allegheny Ludlum Steel Corp. to release the results of further research in stainless steels made with manganese in place of nickel, in order to assure ample future supplies of austenitic stainless steels.

Early work was done in the United States and in Europe during other periods of temporary nickel shortage, and Allegheny Ludlum marketed one such alloy widely during the Korean War. Sensing that the nickel supply problem was certain to recur, the company pursued its developmental program within its own laboratories and in cooperation with customers in the intervening period.

The first chromium-manganese alloy the company offered contains about 15 chromium, 15 manganese, and 1% nickel. This was the material offered during the Korean War, and the low nickel content was dictated by the restriction then placed on nickel content by the government. In addition to this alloy, several others are now available from the company, and still others are under development.

The 15-15-1 alloy described above was generally considered to be a sheet and strip alloy, and has corrosion resistance about equal to the straight chromium grade, Type 430, and slightly inferior to chrome nickel grades of stainless.

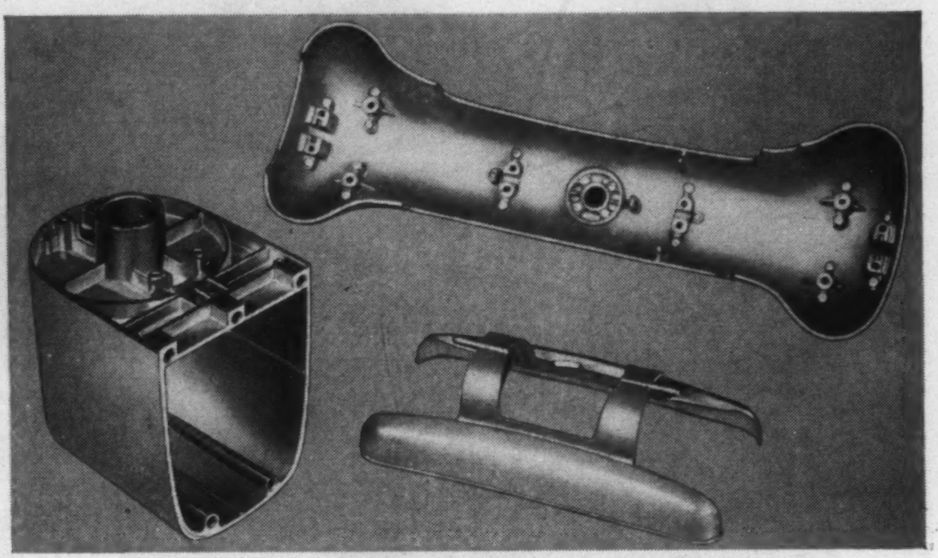
New alloy available

Now available is another sheet and strip alloy with a nominal composition of 17 chromium, 4 nickel, and 6% manganese. This material, while using somewhat more nickel than the earlier grade, will stretch the available supply of the scarce alloying material twice as far as would be possible with the usual grades. This alloy has the desirable high strength and corrosion resistance, the good formability, and the easy weldability of the

DIE CASTING REPORT

Uniformity - - Less Machining - - - Corrosion Resistance - - Close Tolerances - - are a Few Reasons Why

This wringer-type Maytag washer has 24 die-cast parts.



Wringer parts include: gear case, cap and clutch pulley.

Formerly sandcast, this washer cover is now an aluminum die-casting.

Maytag uses 15 to 20 million die cast parts per year!

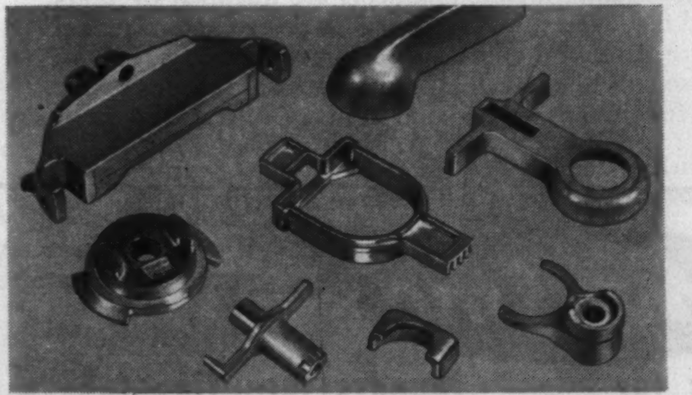
Having produced over 9 million washing machines, no one knows better than Maytag Co. the importance of maintaining quality while meeting high production schedules. Die castings have helped solve the problem – at economical unit costs – by providing unlimited qualities of identical component parts. At the same time, aluminum and zinc die-castings have met the critical demands of functional applications. Examples of Maytag requirements: die castings must be (1) oil and water tight for gear cases and housings (2) true to dimension for line assembly with mating parts and (3) free and clear of external surface flaws.

While Maytag is a large user, those with lower requirements may enjoy similar economies and advantages. Let our creative design engineers look at your functional or decorative part needs, at no obligation of course.

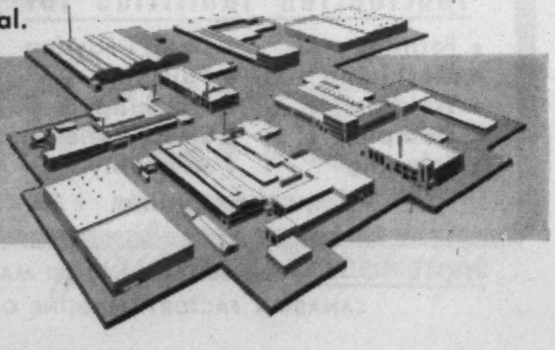
For a copy of: "Die-Castings Unlimited." Address: Precision Castings Company, Inc., 199 Walnut Street, Fayetteville, N. Y.

Switched to die castings from sand castings

Many of the die-cast parts in the Maytag automatic and wringer-type washer were formerly sandcast. Less machining, better surface quality, reduced finishing time are reasons for the changeover. Precision is one of the major die-casting suppliers to Maytag...and has been since 1938.



Small zinc die-cast components, mostly functional.



PRECISION CASTINGS CO., INC.

A SUBSIDIARY OF **Harrisburg Steel** CORPORATION

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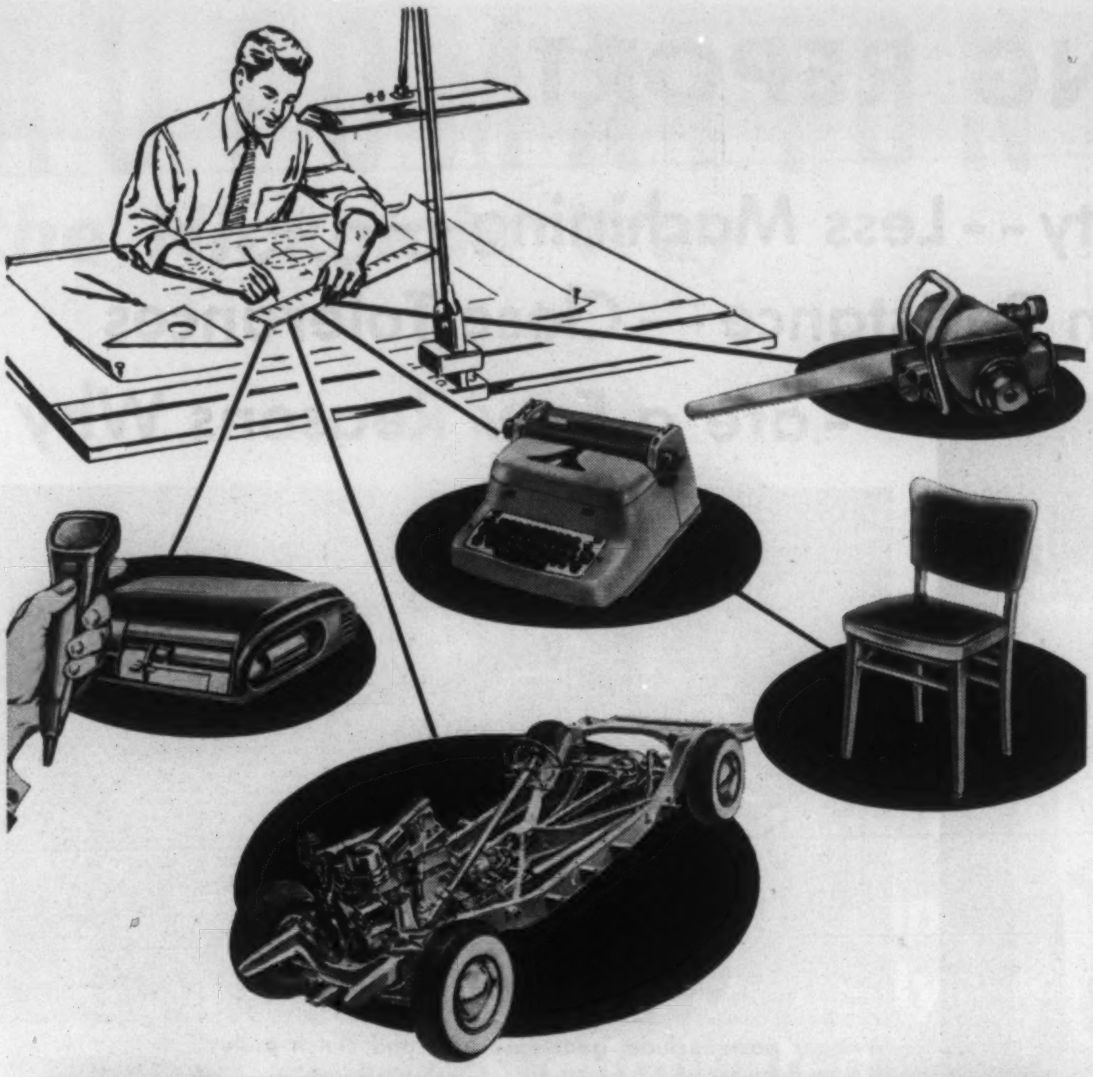

WHO USES MAGNESIUM?

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MATERIALS ENGINEERING NEWS

popular Type 301 which contains 7% nickel.

AL 17-4-6, which has been assigned AISI Type 201, is resistant to atmospheric and most other corrosive conditions where Type 301 may normally be applied. Few, if any changes in tools, dies, or of forming operations are required for a fabricator in changing to this material.

Allegheny - Ludlum also has available another stainless alloy in the same nickel-saving family, this time with a nominal composition of 18 chromium, 5 nickel, and 8% manganese, AISI Type 202. This is an austenitic alloy developed as an alternate for Type 302, and mechanical properties and corrosion resistance are similar to that material. This alloy will probably be available in the future in other products, as well as the sheet and strip now marketed.

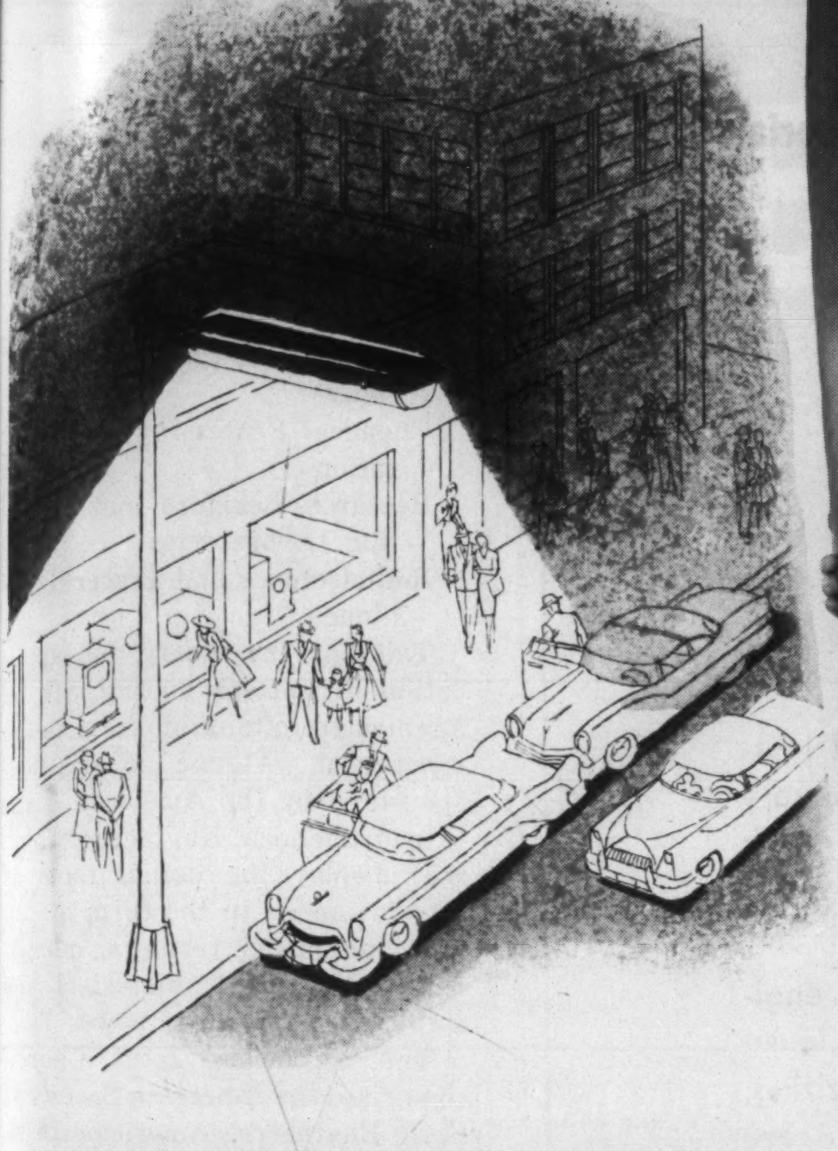
Nuclear Congress Meets in December

Advances in more than 50 fields of atomic engineering and science will be discussed before the more than 2000 delegates to the Nuclear Engineering and Science Congress to be held in Cleveland, December 12 through 16, according to an announcement by the Engineers Joint Council, coordinating body for the Congress.

Representatives of industry, government and education will join with members of 25 national engineering and science societies to learn of the latest nuclear energy developments by outstanding researchers.

The tentative program indicates that the papers to be read before the Congress will cover every major phase of progress in atomic energy, from uranium ore deposits to the new use of radioactive isotopes. Many of these papers have been declassified by the AEC to permit presentation at the Congress.

Continued on p. (264)



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Among the subjects tentatively programmed are:

- Reactor Materials
- Reactor Materials and Design
- Materials and Metallurgy
- Economics in Reactor Design
- Catalysis and Chemical Reactions
- Chemical Processing and Separation
- Research Reactors and Radiation Laboratories
- Radioisotopes and Tracer Techniques

Talks on the theory and application of nuclear energy will be augmented in tangible form in the concurrent Atomic Exposition, sponsored by the American Institute of Chemical Engineers, which will display the actual tools of atomic energy in the form of full size and model reactors, components, equipment, materials and services in the atom power field.

The Engineers Joint Council comprises the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Water Works Association, American Institute of Electrical Engineers, The Society of Naval Architects and Marine Engineers, American Society for Engineering Education, The American Society of Refrigerating Engineers, American Institute of Chemical Engineers, The American Institute of Industrial Engineers.

Other sponsors cooperating with Engineers Joint Council in this Congress are the American Chemical Society, American Institute of Physics, Institute of Radio Engineers, American Nuclear Society, American Geological Institute, American Society for Metals, American Rocket Society, Institute of Aeronautical Sciences, Atomic Industrial Forum, Society of Automotive Engineers, American Society for Testing Materials.

The Cleveland hosts for the Congress are the Cleveland Engineering Society and the Cleveland Technical Societies Council.